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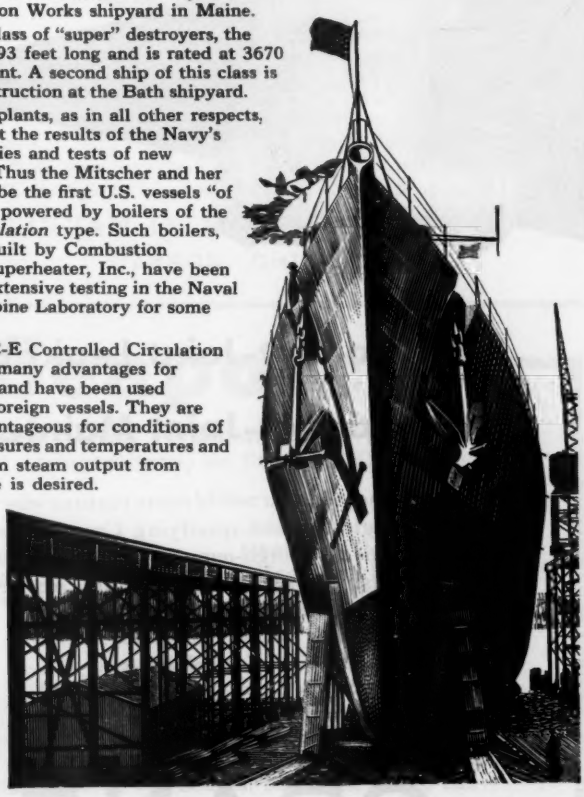

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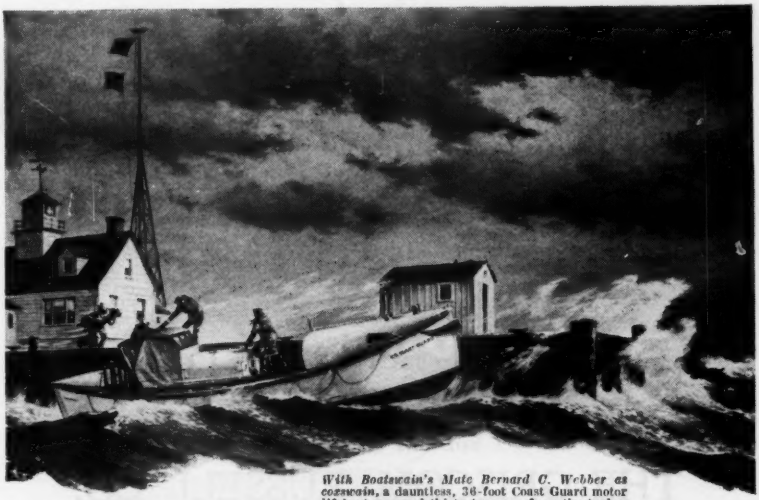

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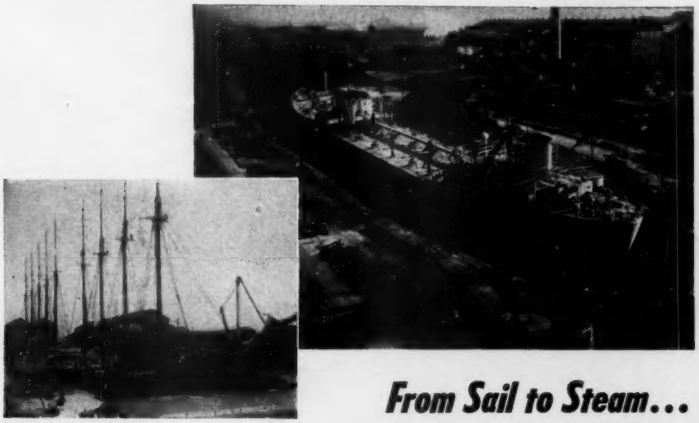

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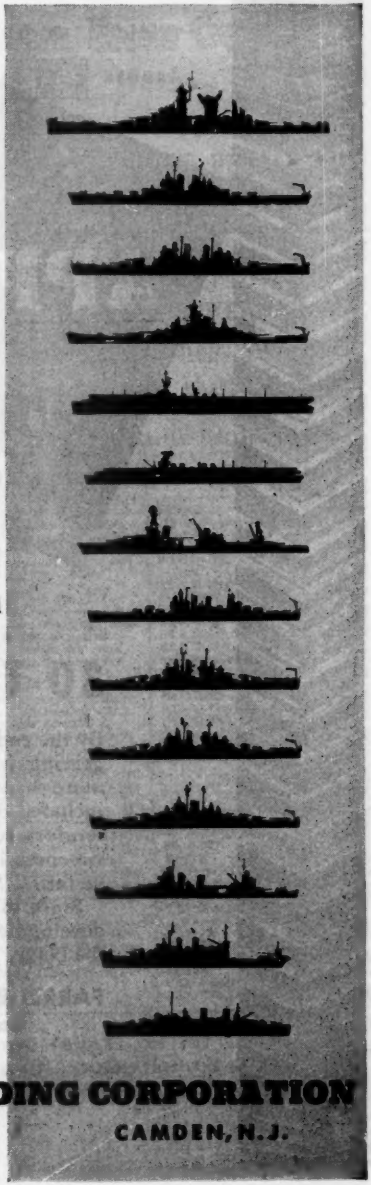

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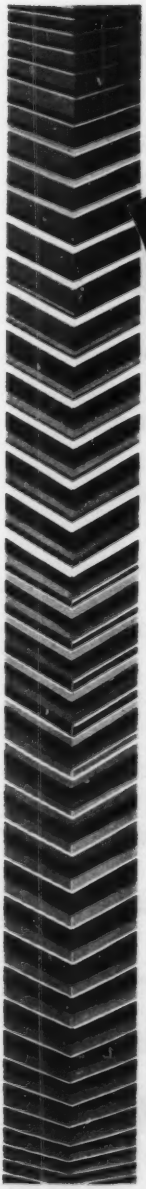

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STEEL	"PERMADINE" Zinc Phosphate Coating Chemical	Rust and corrosion prevention	Nuts, bolts, screws, hardware items, tools, guns, cartridge clips, fire control instruments, metallic belt links, steel aircraft parts, certain steel projectiles and many other components.	MIL-C-16232 U.S.A. 57-0-2, Type II, Class B U.S.A. 51-70-1, Finish 22.02, Class B Navy Aeronautical M-364 U.S.A. 72-53 (See An-F-20)
STEEL	"THERMOIL-GRANODINE" Manganese-iron Phosphate Coating	Wear-resistance anti-galling, safe break-in of friction or rubbing parts. Rust proofing.	Friction surfaces such as pistons, piston rings, gears, cylinder liners, camshafts, tappets, crankshafts, rocker arms, etc. Small arms, weapon components. Hardware items, etc.	MIL-C-16232 U.S.A. 57-0-2, Type II, Class A U.S.A. 51-70-1, Finish 22.02 Class A Navy Aeronautical M-364 U.S.A. 72-53 (See AN-F-20)
STEEL	"GRANODRAW" Zinc-iron Phosphate Coating	Improved drawing, extrusion, and cold forming	Blanks and shells for cold forming, heavy stampings; tube; tubing for forming or drawing; wire; rod; etc.	———
ALUMINUM	"ALODINE" Protective Coating	Improved paint adhesion and corrosion resistance	Aluminum products of similar design such as refrigerator parts, wall tile, signs, washing machine tubs, etc; aircraft and aircraft parts; bazookas (rocket launchers), helmets, belt buckles, clothes dryers, clothesline, rocket motors, etc., aluminum strip or sheet stock.	MIL-C-5541 (See also QPL-5541-1) MIL-S-5002 AN-F-20 U.S. Navord O.S. 675 16 E4 (Ships) AN-C-170 (See MIL-C-5541) U.S.A. 72-53 (See AN-F-20)
ZINC	"LITHOFORM" Zinc Phosphate Coating Chemical	Improved paint adhesion	Zinc alloy die castings; zinc or cadmium plated sheet or components; hot dip galvanized stock; galvanneal; signs; siding; roofing; galvanized truck bodies; etc.	QQ-P-416 RR-C-82 JAN-F-495 AN-F-20 U.S.N. Appendix 6 U.S.A. 72-53 (See AN-F-20)

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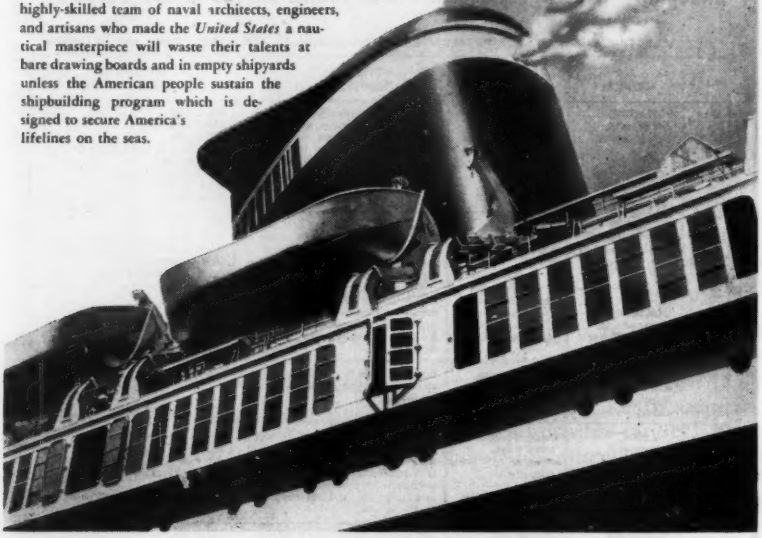

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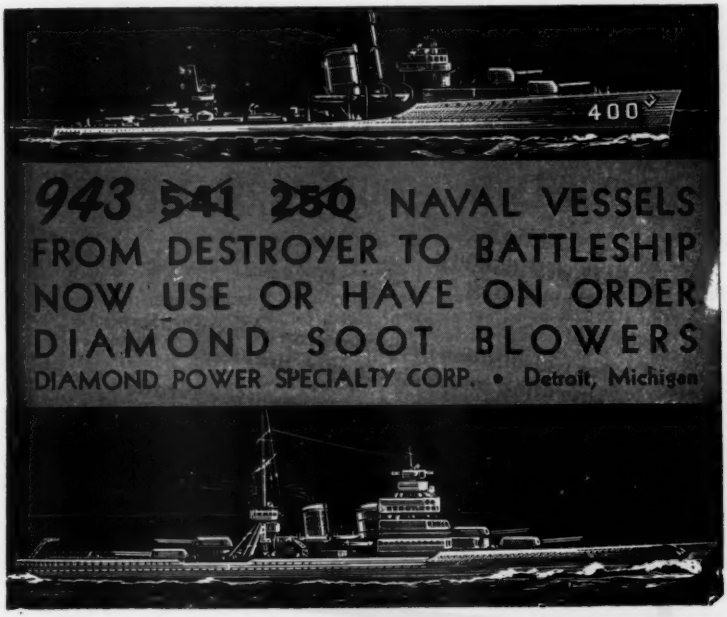
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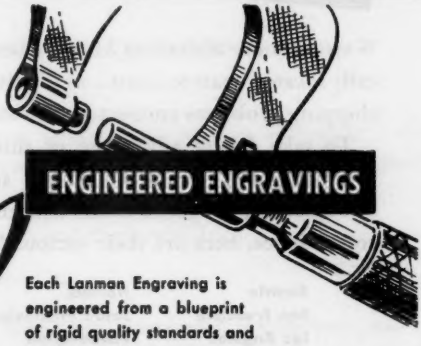

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SECRETARY'S NOTES

Annual Meeting

The Society's annual meeting was held on 7 October 1952. The following report from the nominating committee was received:

"7 October, 1952

The American Society of Naval Engineers, Inc.,
Washington, D. C.
Gentlemen:

The committee, of which the undersigned is Chairman, and of which Captain W. A. Dolan, Jr., U.S.N., Commander E. C. Thompson, Jr., U.S.C.G., Captain Walter L. Tann, U.S.N.R., and Mr. John F. Hanlon are the other members, appointed by Rear Admiral T. C. Lonnquest, U.S.N., President, in accordance with Section 23 of the By-Laws, by his letter of 2 September, 1952, to present nominations for offices of the Society at this Annual Meeting, presents the following nominations:

For President

Rear Admiral H. N. Wallin, U.S.N.

For Secretary-Treasurer

Captain J. E. Hamilton, U.S.N., Ret.
Captain W. R. Millis, U.S.N., Ret.

For Members of Council

Regular Navy Officers

Rear Admiral E. W. Sylvester, U.S.N.
Captain G. M. Chambers, U.S.N.
Captain C. L. Engleman, U.S.N.
Captain W. L. Pryor, U.S.N.
Captain C. S. Seabring, U.S.N.
Captain P. W. Snyder, U.S.N.

Naval Reserve Officers

Captain R. E. W. Harrison, U.S.N.R.
Lieut. Commander J. W. Sawyer, U.S.N.R.
Captain T. H. Urdahl, U.S.N.R

Civilians

Mr. H. E. Carleton
Mr. W. N. Ruby, Jr.
Mr. T. H. Shepard

Respectfully sumbitted,
Henry Williams, Rear Admiral, U.S.N., Ret.
Chairman"

The membership accepted the report and made no additions thereto.

Ballots are being mailed out to members of the Society.

Annual Banquet

At the annual meeting the membership voted unanimously to hold the 1953 annual banquet at the Statler Hotel in Washington on

FRIDAY, 1 MAY, 1953.

The banquet committee will be appointed by the president in the near future and members will be informed of its actions through the usual banquet notice with application blank. These will reach the members by 1 March 1953. Members are requested to withhold making their applications until the notices and application forms are received.

Correction

The Secretary has received word from Commander Arthur C. Bushey, Jr., U.S.N.R., that his article, "United States Navy Rubber Craft", published on pages 621 to 625 of the August 1952 issue of the JOURNAL, was co-authored by Mr. Charles E. Miller. The article as published did not indicate Mr. Miller's participation in its preparation.

Mr. Miller served his apprenticeship in a yacht designer's office, following which he had two years service in the Design Division of each of the New York and Boston Naval Shipyards. In 1939 he joined the Boat Design Section of the Bureau of Ships, where he has been largely responsible for the design of inflatable rubber boats since the Bureau became actively interested in this type of craft.

Miscellaneous

Last June the following Bureau of Ships letter was sent to the manufacturers of electronics equipment. It is reproduced herein because it shows the emphasis currently being placed on efforts to improve reliability of electronics equipment, to decrease maintenance and to promote simplicity of operation.

"Attention Technical Director for Research and Engineering

Gentlemen:

Subj: Electronics; project simplification

The increasing complexity and resultant increased maintenance and reduced reliability of electronics equipment is a matter of great concern to the Bureau of Ships. Every effort is being made by the Bureau of Ships to simplify the design of electronics equipment. To successfully accomplish our objective, the full cooperation of the engineering staffs of all Bureau of Ships contractors is needed.

The Bureau of Ships solicits and will welcome proposals from contractors which will result in the production of less complex and more easily maintained equipment. Such proposals for simplification of designs are desired any time during the performance of existing contracts and will be evaluated on a not-to-delay production basis. It is understood that under no circumstances shall changes be invoked in existing contracts unless authorized by formal change under the contracts.

In order to insure proper evaluation by the Bureau of proposals for simplification of design, it is requested that the proposal completely set forth any existing specification requirements which cannot be fully met. Such proposals should also recommend specification changes which will be necessary to accomplish the proposed simplification.

Proposals for simplification of designs on existing contracts should be forwarded to Bureau of Ships, Electronics Design and Development Division, Code 810, Washington 25, D. C.

Sincerely yours,

/s/ H. E. BERNSTEIN
Acting Assistant Chief of Bureau
for Electronics"

STRUCTURAL BEHAVIOR IN SHIPS AT SEA

CAPTAIN E. A. WRIGHT, USN AND MR. JOHN VASTA

THE AUTHORS

CAPTAIN WRIGHT is Chairman of the Ship Structure Subcommittee, Chairman of the Hull Structure Committee of the Society of Naval Architects and Marine Engineers, and Head of the Hull Design Branch of the Bureau of Ships. He was formerly Head of the Hydromechanics Laboratory and Deputy Technical Director of the David Taylor Model Basin.

MR. VASTA is Head of the Hull Scientific Design Section of the Bureau of Ships, and member of the Ships Structure Subcommittee. He has held many responsible positions in the design and research of ship structures, and has had extensive experience in the planning and carrying out of full scale ship structure tests. He was formerly associated with the U.S. Experimental Model Basin engaged in structural research.

EDITOR'S NOTE

This study was prepared for presentation at the first meeting of the newly-formed Committee on Ship Structural Design of the National Research Council—National Academy of Sciences, advisor to the Ship Structure Committee. Publication has been prompted by indications of a more widespread interest in the subject.

INTRODUCTION

The hull structure of a ship at sea is subjected to the most complex and variable loading known to design engineers. The purposes of this paper are to review past efforts at observations of structural behavior in ships at sea, and to draw tentative conclusions from the data presently available.

The approach of naval architects to the intricate problem of stresses in a ship at sea has been principally from two directions. First, assumptions are made of loadings, and stresses are calculated on the basis of statics. The customary balancing of a ship on a stationary wave of length equal to the length of the ship and of height equal to 1/20th of the length is the best known example of this kind of static assumption. As other examples, the maximum

wave height at a point along the ship's side is assumed, from which a ring-frame calculation is made for the required strength of transverse frame; or the period and maximum angle of roll are estimated and designs of masts and other structures are based on calculated inertia forces and gravity components. The second direction of approach has been the evaluation of service experience. Throughout the years, structural weaknesses which have developed in ships at sea have been studied, corrective measures have been taken, and design formulas modified accordingly.

The design method, based on static assumptions and on service experience, has produced generally effective hull structures believed to be reasonably well engineered to carry out their functions. However, the method is not entirely satisfying. Possibly some hull structures are still heavier than need be, and represent dead weight that could be more profitably carried in cargo or armament. Perhaps some of the usual static assumptions for the hull girder and its components do not truly represent actual structural loading patterns in a ship at sea. Consequently, even when structural weaknesses do appear, a rational analysis is not always possible because the very nature of the loading may be incompletely defined. For the sake of realism, and in appreciation of the continuing need for improvements in hull design, the naval architect looks at the structural behavior in ships at sea with intense and objective curiosity to learn more about the actual loadings to which his structures are subjected.

ELEMENTS OF THE PROBLEM

The infinitely varying free surface that is the sea, changes continuously the distribution of buoyancy acting on the hull. This random migration of buoyancy with the shape of the air-water interface produces correspondingly random variations in the direction and magnitude of the principal strains induced throughout the hull structure. Buoyancy, shifting in both magnitude and center of effort, accelerates the structure as a whole in six degrees of freedom, and produces superimposing strains due to ship motions. Finally, accompanying the relatively majestic strains associated with buoyant forces and ship motions, there are the dynamic forces due to slamming, pounding and wave impact that send pulsing strains reverberating through the hull, and leave the hull quivering to the blow, as in Figure 1. Therefore, strains in a hull structure at sea can be classed generally as those due to:

Buoyancy
Motion
Impact

A ship structure is an elastic body operating in a fluid of comparatively low compresssibility. The elastic properties of the water assume importance only when the loading pulse is so rapid that it may be considered as a shock wave, such as that from an underwater explosion. The elastic properties of the ship, on the other hand, may be very significant in regard to structural response in a seaway. It is important to recognize, therefore, the distinction between external loading and internal response. The measurement of the pressure on a ship's bottom is an observation of the external loading, whereas the measurement of the strain in the structure is an observation of the internal response. In considering the behavior of ships at sea, it seems advisable to separate the observations into the two categories:

Loading
Response

Both are essential to describe fully the structural phenomena.

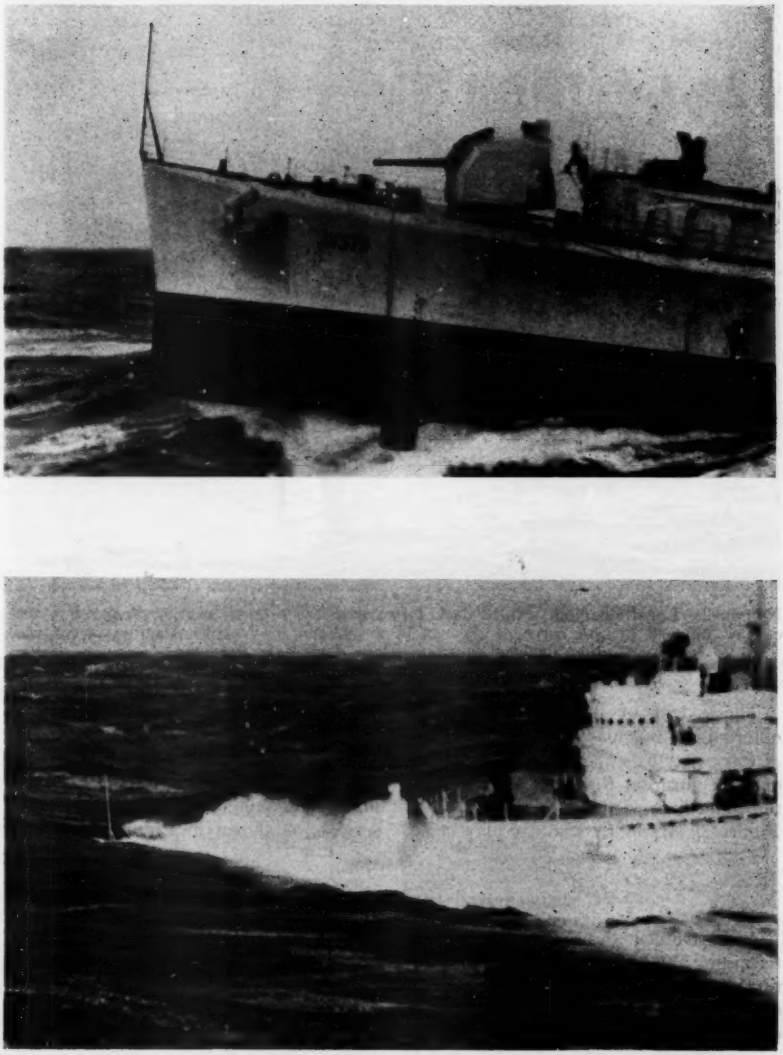


FIGURE 1. Buoyancy, Motion, and Impact act on the USCGC *Matagorda* in heavy seas on North Atlantic weather station.

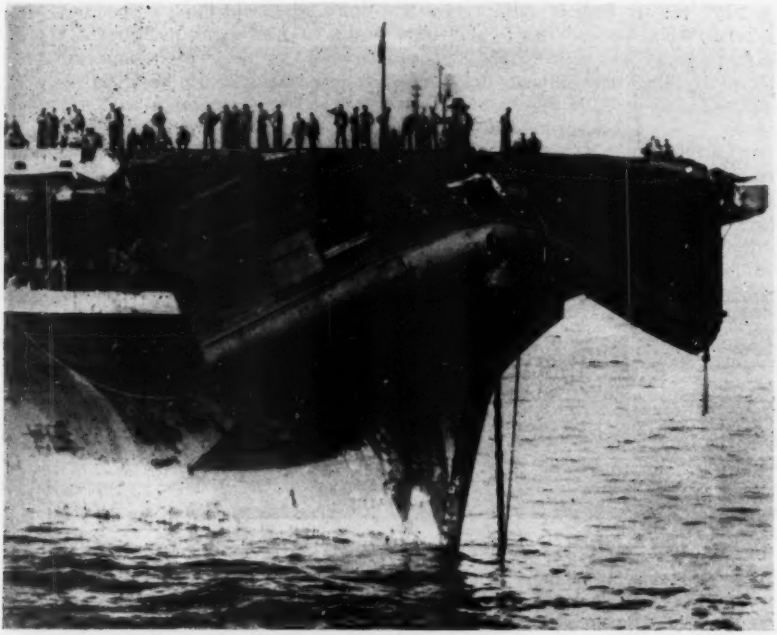


FIGURE 2. Local Loading. Flight deck forward in the aircraft carrier *Bennington* was carried upward by the force of the sea in a typhoon in Western Pacific waters, and then dropped down to drape itself over the bow.

The extent of internal response to external loading may vary considerably. A force may be sufficiently localized and of such duration that only structure in the immediate vicinity is affected, as in Figure 2. Again, a local load may bring a general structural response, such as when wave slap at the bow excites whipping of the hull girder. When the effects of severe general and local loadings are combined, the results can be serious, as shown in Figure 3.

DEVELOPMENT OF INSTRUMENTATION

As instrument design has been a determining factor in measuring the structural behavior of ships at sea, a few developments will be described before discussing the service observations.

Representative of pioneering and simple design, the latchkey scratch gage, Figure 4, developed by Professor A. V. de Forest, is actually lighter and smaller than its namesake. A scratch arm, fastened to one gage point, slowly traverses a target secured to the other gage point. To separate the scratches for successive strains, the arm is rotated slowly by the fulcrum spring, but the rate of movement is not sufficiently uniform to use for a time scale. The record of movement between gage points is to actual scale, and must be magnified optically to obtain readings.

FIGURE 3. Combined Loading. Decks and ship sides forward in the cruiser *Duluth* are buckled in a 120-knot typhoon in the Pacific.

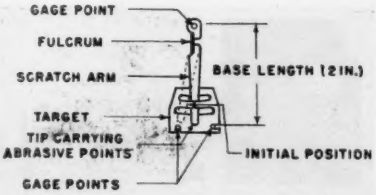
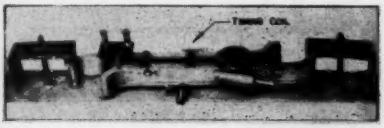


FIGURE 4. Latchkey Scratch Gage.



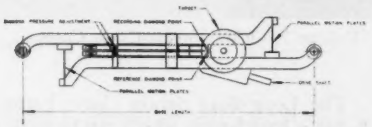


FIGURE 5. EMB Circular Target Scratch Gage. Recording End of Gage.

The principal development work in the United States on mechanical extensometers has been done by the Experimental Model Basin, and its successor, the David Taylor Model Basin. Examples of early developments [1],* are:

Circular Target Scratch Gage
Long-Base Strain Gage
Stress-Cycle Counter

The Circular Target Scratch Gage, Figure 5, is a modification of the Whittemore hand strain gage. A small rotating table, driven by an independently mounted electric motor, supports on its underside a chromium-plated brass target on which the record is scribed by diamond points. One complete revolution of the target is made in about 4 hours, and synchronization with other stations is obtained by a small electric hammer which marks the record.

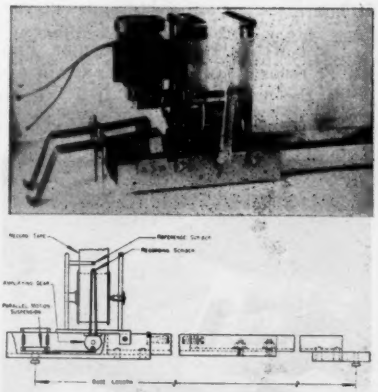


FIGURE 6. EMB Long-Base Strain Gage.

*Numbers in brackets indicate references at the end of the paper.

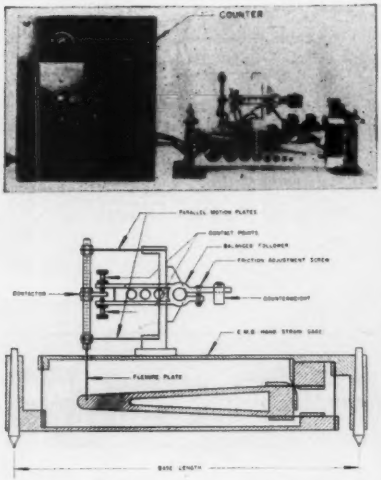


FIGURE 7. EMB Stress-Cycle Counter.

The Long-Base Strain Gage, Figure 6, has a base length which can be varied between 4 and 6 feet in length by an adjusting screw. Amplification is mechanical, with a 10 to 1 linkage, and the record is scribed on waxed paper as in a tape chronograph. The 50-foot roll of paper will run continuously for 10 hours.

The EMB Stress-Cycle Counter, Figure 7, records only when the strain exceeds the value at which it is set to operate. The relay circuit is designed to register when each of the contact points is closed in turn. A counter totals the number of cycles.

The metalectric gage, generally known as the SR-4 electrical strain gage, came into use in the early 40's and has exerted a great influence on the technique for measuring strains in ship structures, especially under dynamic loading, [2]. The SR-4 strain gage brought important advantages over other types. It is extremely light, is readily cemented to the structure, and has negligible inertia. It has a short base length which makes it more useful for localities of steep strain gradients. Since changes in strain cause only minute changes in electrical resistance in the gage element, electronic amplification is need to insure an output which can be recorded permanently on an oscillograph or read visually on a meter. Hence, while the gage itself is very simple, Figure 8, it requires complex [3] and weighty electronic gear, Figure 9.

FIGURE 8. The SR-4 Strain Gage.

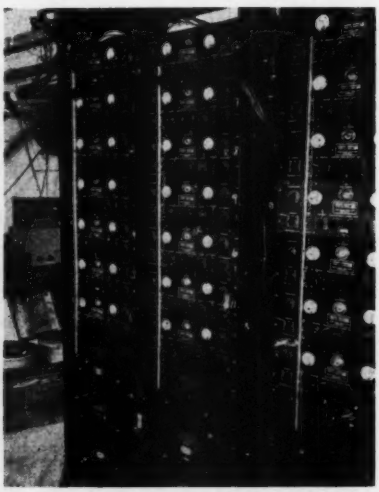


FIGURE 9. Electronic Gear Installed in the Ice-Breaker *Mackinaw*.

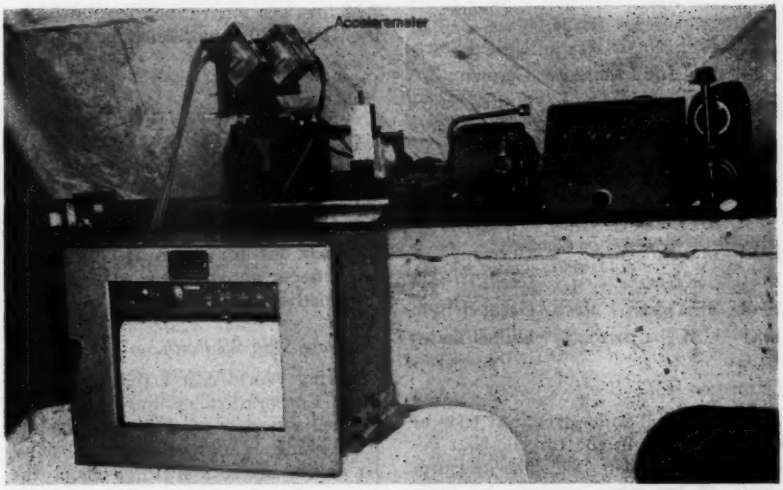


FIGURE 10. Recorder and Accelerometers.

Modern development in strain instrumentation [4] [5] [6] [7] includes the:

Automatic Motion Recorder

Strain Cycle Gage and Counter

The Automatic Motion Recorder, Figure 10, registers as a function of time the output of 5 channels which can indicate either strain or ship motion. The instrument is completely automatic and requires no operator to accompany it at sea. The unit is essentially a direct recording oscillograph which can be set to sample the strains or motions by recording for a few minutes at specified intervals. The pattern can be varied by manual control, so that special records can be obtained, after which the machine reverts to automatic sampling.

The TMB Strain Cycle Gage and Counter automatically tabulates the number of cyclic variations of selected strain amplitudes, and classifies them according to the mean strain levels about which these cyclic variations occur.

The trend in instrumentation [7] is toward an apparatus that will automatically perform the functions of sampling, recording, and analysis.

OBSERVATIONS AT SEA

Over the past half-century, a number of dauntless investigators have made efforts to measure the forces acting on a ship in a seaway and the resulting deflections and strains in the ship girder. Notable among these expeditions are:

Year	*Ship*	*Country*
1905	HMS *Wolf*	Great Britain
1913	SS *Ancon*	United States
1918	SS *Faith*	United States
1919	SS *Westboro*	United States

Year	*Ship*	*Country*
1930	USS *Cuyama*	United States
1934	MS *San Francisco*	Germany
1936	Destroyers *Dewey* and *Flusser*	United States
1939	Cruisers *Phoenix* and *St. Louis*	United States
1939	MS *Duisburg*	Germany
1944	SS *Niso*	Great Britain
1948	SS *Ocean Vulcan*	Great Britain
1951	USCG *Casco*	United States

Destroyer HMS Wolf

The first full-scale structural tests at sea were those in the torpedo-boat destroyer HMS *Wolf* [8]. The measurements at sea were confined to three locations at one transverse section. One strain gage was placed at the vertical keel, and two on the deck, port and starboard. Coordination of observations at sea was achieved by having observers stationed close to the strain gages and instructed to read the dials when bells were rung.

One of the most severe loading conditions observed occurred when the *Wolf* was light, steaming ahead into a sea at 12 knots through a squall which attained the force of a moderate gale (Beaufort 7). Strains were notably high when the vessel was steaming at fast speed with head on to wind and sea, her bow lifting and riding on one wave and then diving into the next. In crossing the seas obliquely, which produced combined pitching and rolling, stresses were much less than in pitching only.

The maximum stresses recorded during the sea trials, which included steaming through steep ship-length waves, were 5.38 tons per square inch tension in the keel and 2.88 compression in the deck. In comparison, the calculated stresses in a standard L/20 wave were 7.14 tons per square inch tension in the keel, and 5.30 compression in the deck.

Cargo Ship SS Ancon

Strain measurements in the shelter deck cargo ship SS *Ancon* [9] were made with a scissors type of gage to magnify the readings. Strains due to pulsations from the engines were found to be of the same order as those due to ship motions in a seaway. Temperature effects obscured the strains from slow load shifts.

Concrete Ship SS Faith

During World War I, the Emergency Fleet Corporation designed and constructed a fleet of steel cargo ships and ocean-going reinforced concrete ships. To obtain better knowledge about the stresses that the ships would experience at sea, together with the forces that the sea exerts on the hull, the Corporation developed instruments to record strain and water pressure [10]. A total of 24 long-base extensometers (straingraphs) were built. Only 8 straingraphs were ready for the voyage of the *Faith* in 1918, the first concrete ship to go in service. At sea, a maximum stress range of approximately 3.1 tons per square inch was recorded on the longitudinal reinforcing steel in one of the main longitudinal deck beams. The stress measurements were reassuring by indicating that the stresses actually experienced by the ship even in moderate storms were well under the design stresses.

Cargo Ship SS Westboro

The observations made in the steel cargo ship *Westboro* [10] during a transatlantic voyage in 1919 were more extensive than those made in *Faith*. Strains were measured simultaneously at from 8 to 22 points on the main transverse section of the ship, as in Figure 11. These strains were sufficiently consistent to permit drawing the longitudinal stress distribution at the midship

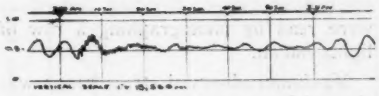


FIGURE 11. Pounding record from steel ship *Westboro*; taken on shell plate one foot below bridge deck; bow of ship after lifting out then slamming in heavy sea.

section. Though there were some irregularities, it was established nonetheless that the ship girder acted as a simple beam in bending, Figure 12. The maximum stress range was of the order of 3.6 tons per square inch. The significance of these tests lies in the fact that relatively simple and rugged instruments were developed as early as World War I which could measure the structural behavior of the hull when subjected to sea forces.

With the ending of the War, the shipbuilding industry suffered a serious relapse. The merchant fleet was laid up, the organization responsible for its design and management was disbanded, research and investigation ceased. Nothing was done in the field of observation at sea until the early part of 1930 when the U. S. Navy undertook a series of important studies.

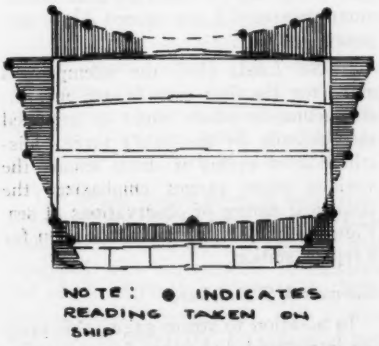


FIGURE 12. Measured stress distribution in *Westboro* — ●denotes stress intensity averaged from 49 reversals.

Naval Tanker Cuyama

For a period of 50 days of operation in 1930, bending strains were recorded in the Naval Tanker *Cuyama* [11] [12]. Instrumentation included extensometers having a base length of 25 feet, which registered displacements in the order of ¼ inch.

Bending moments of about 140,000 foot-tons in sag, and 210,000 foot-tons in hog were deduced from the measured strains, which corresponded to about 6.9 and 10.3 tons per square inch respectively. Loads at sea in hog were consistently higher than in sag, as shown by Figure 13.

Motorship San Francisco

In the Autumn of 1934, the German Motorship *San Francisco* departed Hamburg on a historic voyage. The cargo she carried was doubtlessly important to her owners, but naval architects remember only her secondary mission—to measure the waves and the corresponding ship's motion, vibration, strains and deflections [13] [14] [15]. Dr. Schnadel's account says: . . . "We were decidedly fortunate on the return voyage in the Atlantic. We there encountered heavy swells several times and two very

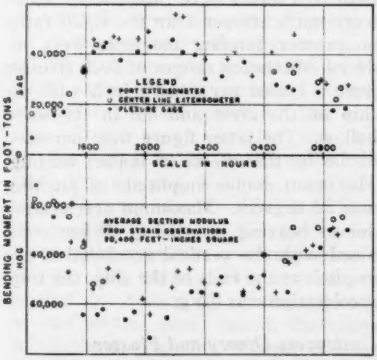


FIGURE 13. *Cuyama*, February 1930. Maximum Bending Moment in each hour while ship was heading into moderate swell enroute to Port Arthur.

violent storms of 20 and 30 hours' duration. . . . The barograph indicated a rapid fall in atmospheric pressure . . . The lowest pressure was below the lowest recording limit of the barograph . . . In the squalls the wind rose to 40 meters per second (90 miles per hour) and for just a few hours . . . the wind attained 12 on the (Beaufort) scale . . . Observation of the seas from the bridge . . . showed waves with a height of at least 15 meters. Actually, stereophotogrammetric records showed a maximum distance of from 16 to 18 meters from the highest to the lowest point."

In addition to wave measurement with the stereo-camera, the position of the water relative to the ship, the wave profile, was recorded by photographing a bank of lamps which lighted when contacts outside the hull were closed by sea water. At the same time, pressure gages recorded the forces exerted on the hull by the seaway. The deflection of the hull was recorded by photographing a line of lights. Strain gages were of the scratch recording type, synchronously connected.

As in *Wolf* and *Cuyama*, observations in *San Francisco* showed that stresses are higher when the ship is in the wave hollow than when on the wave crest. Although waves were encountered which were much steeper than the L/20 ratio, no greater bending moments were induced. Maximum ranges of deck stresses were 4.1 tons per square inch with the ship on the crest and 4.6 in the wave hollow. The latter figure was increased to 5.8 by the effects of impact loading. Maximum double amplitude of pitching was 22 degrees. Maximum acceleration due to heaving was 0.3 g. When combined with the vertical acceleration due to pitch at the ends of the ship, the total acceleration was 0.5 g.

Destroyers Dewey and Flusser

On the destroyer *Dewey* [16] strain distribution at sea was measured by 50 latchkey scratch gages and 18 other mechanical gages. Bending deflections were read by photographing a row of lights end on.

Maximum observed stress range was about 4.5 tons per square inch. There was some indication that the maximum ratio of bending moment to moment of inertia was forward of amidships, possibly near the break in the forecastle desk, and fairly definite evidence that the neutral axis was above its calculated position by a foot or more.

In *Flusser* [16], shearing strains were measured, as well as longitudinal strains. For this purpose, rosette gages were installed. Photographic recorders were used extensively to register the readings of the gages. The expense of this type of equipment and the effort required to analyse the data were emphasized in the report.

Every effort was made to strain the ship in the slight ground swell that persisted during the cruise, but the maximum stress was only about 1.5 tons per square inch.

Cruisers Phoenix and St. Louis

In *Phoenix* [16], the EMB stress cycle counter and long-base strain gage were used for the first time. Accurate records were obtained, but the seas were too flat throughout the cruise to produce strain data of much interest. Maximum stresses did not exceed 2 tons per square inch.

In *St. Louis* [16], the attempt was made for the first time to use only instrumentation which could be attended satisfactorily by the ship's force. Distribution of cycles of stress among the various stress ranges emphasized the statistical nature of observations at sea. Figure 14 shows such a distribution for a typical station.

German MS Duisburg

In addition to strain gages, this project introduced dial gages for measuring the bending in the open panels. The effect of temperature tended to obscure

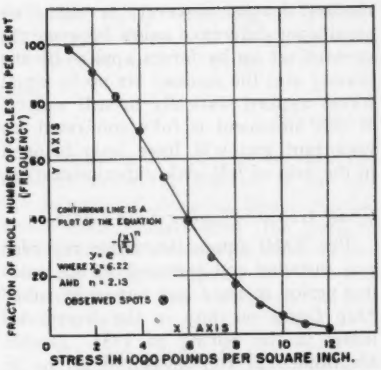


FIGURE 14. *St. Louis*, August 1939. Stress in second main deck longitudinal, Frame 71½ starboard.

the smaller strain measurements [17]. It was found that a theodolite is a very unreliable instrument for measuring vertical hull girder deflections in a seaway.

Tanker Niso

In late 1944, the newly organized Admiralty Ship Welding Committee, spurred by the persistent ship fracture problem affecting many vessels built during the last war, directed its attention to the problem of service strains. Arrangements were made to install experimental gear aboard the tanker *Niso* [18] for a trip across the Atlantic to evaluate the workability of the instruments under actual sea conditions. Direct-measuring, automatic-recording strain gages were installed, and on the 24th of December 1944, the ship departed for New York in ballast.

The strain gages were of two types; electrical resistance type, and variable inductance choke type. *Niso* was also equipped with instruments to measure the elastic deflection of the hull. This was accomplished optically, with a camera, and mechanically, by means of two 80-foot trusses, erected on the deck and so arranged as to record changes in curvature of the hull. To measure the water pressure on the hull, a deflection type of diaphragm pressure gage, with remote reading variable reluctance choke, was used. The actual form of the surface of the sea was recorded by a pair of aerial-survey type cameras, arranged stereoscopically. In addition, electrical contacts, similar to those used on *San Francisco*, measured the trace of waves on the ship's side. The accelerations that the vessel underwent at sea were measured in three directions, and roll and pitch were gaged by gyroscopic recorders.

The voyage of *Niso* was primarily for evaluating the workability of the instruments. Some of the quantitative data are significant however. Under weather and sea conditions which were described as "fairly severe" but "probably much less severe than those which might have been encountered," the maximum range of observed strains represented a total stress change of 3.2 tons per square inch.

Ocean Vulcan

The experience gained with the instruments tried in *Niso* served in good stead for the trials of *Ocean Vulcan* [19]. This vessel was thoroughly equipped for sea observations. The aims of the tests were the determination of the loads and forces that the sea exerts on the structure, the delineation of the wave form, and the resulting stresses induced in the hull structure. The same type of instrumentation that was used on *Niso* was installed on *Ocean Vulcan:* the areas covered, however, were of a much larger extent. The significant thing about the *Ocean Vulcan* observations is the complete synchronization of all the data taken. This was accomplished by recording photographically, at one central panel board, the output of all the instruments, relating the data to one common time axis. In this manner it was possible to define the ship's position in relation to the wave system at any instant, and note the associated

strains experienced by the structure. With the advances made in instrumentation and techniques of measurement during the 1930-40 decade, the sea trials of *Ocean Vulcan* constitute an important milestone in the field of measurements at sea.

The stresses experienced by *Ocean Vulcan* during her voyages reflect the various sea conditions. In waves of up to 400 feet in length and 18 feet in height, amplitude of stress change amidships was about ±1½ tons per square inch (*Ocean Vulcan* is 416 feet in length). Voyage 6 was the roughest. Waves were estimated at 500 feet in length, with a height of 30 to 35 feet. The wind was at full-gale, and for some time the ship was forced to heave to. Under this sea condition, which corresponds to a Force 8 on the Beaufort Scale, stresses were of the order of ±4 tons per square inch.

The voluminous data collected on these voyages have not been completely digested and reported. A tentative conclusion drawn, however, is that "no significant difference exists between the stresses set up by forces applied by the seaway and the stresses set up by equal forces applied statically in still water." If this statement is fully confirmed, an important gap will have been bridged in the field of full-scale experimentation.

Coast Guard Weather Ship Casco

The TMB automatic motion recorder was installed and operated during a 32-day period in the Coast Guard Weather Ship *Casco* on duty in the North Atlantic in the Spring of 1951. Double amplitudes in roll measured up to 35 degrees, and double amplitudes in pitch up to 20 degrees. The double amplitudes of the angular accelerations were 0.25 radian per second for both roll and pitch. Heaving acceleration underwent changes up to 0.5 g (double amplitude). Maximum stresses due to the action of the sea did not exceed 1.5 tons per square inch, although the waves encountered were about 260 feet long (*Casco* is 300 feet long) and about 15 feet high.

DISCUSSION

Ships instrumented and prepared to obtain structural strain measurements found fair weather and smooth sailing most of the time. The low probability of experiencing strains approaching those for which a hull is designed, and the random nature of the individual observations, emphasize the necessity for using a statistical approach to structural behavior at sea.

The overall indication from service observations of structural behavior is that stresses amidships in ships at sea are no higher than the stresses calculated by the traditional balancing of the ship on an L/20 wave. Observations to date are therefore in the comforting direction.

Evidence is clear that stresses in a seaway in the sagging condition exceed those in the hogging condition. This behavior is believed to be due chiefly to inertia forces acting on the ship and to rotation of the water particles, factors neglected in the static strength calculation. Emphasis is placed thereby on the strength of the deck in compression, and the strength of the bottom in tension.

The least observed and the least understood phenomenon is that of wave impact. It appears that the troublesome stresses due to wave impact occur when a ship plunges into a wave hollow, and the resulting transient stresses add to the hogging stresses. Although there is evidence that the force of local impact can be extremely high, the augmentation of stress amidships seems to be

moderate, rarely exceeding 15 percent of the total stress. A wave impact in synchronism with whipping excited by a previous impact is a possibility and will need watching in future observations.

TENTATIVE CONCLUSIONS

Recognizing the paucity of observations of structural behavior at sea and the hazards of drawing broad conclusions from limited data, the authors have examined the service observations from the designer's point of view, and have concluded that these are the following trends:

a. Maximum hull stresses occur in waves whose length is approximately equal to the length of the ship.

b. Observed stresses are generally less than calculated stresses based on an L/20 static wave.

c. Stresses are greater when a ship is in a wave hollow than when a ship is on a wave crest.

d. Stresses due to wave impact are strongly influenced by the relative velocity of ship and wave, increasing as the relative velocity increases.

e. In combined pitching and rolling, as when crossing the seas obliquely, stresses are very much less than those in pitching only.

f. Waves in the order of 400 to 500 feet long may have wave height to length ratios as high as 1/14, compared to a ratio of 1/20 used in the usual longitudinal strength calculation.

g. Maximum stresses amidships in ships ranging between 300 to 500 feet in length in severe weather have been in the order of 4 to 6 tons per square inch.

h. Strain and motion data from ships at sea are difficult to analyse, and the statistical approach appears to be the only practicable one.

FUTURE WORK

The tentative conclusions which the authors have had the temerity to draw are based on a minuscule amount of data. On the other hand, broad coverage of all the variables in structural behavior of ships at sea would require an unreasonable proportion of the total research effort available to naval architects. Therefore, future work is planned along the following simplified lines:

a. Sampling of ship motions, bottom pressures, and strain levels at sea by unmanned recorders in several ships [6].

b. Model experiments in which the variables can be readily controlled and observed, and in which the reactions in the hull girder due to hydrodynamic loading can be measured [20].

In seaworthiness studies and in structural observations, the dynamics of ships at sea are receiving searching scrutiny from which will surely come understanding and progress.

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HEAT TRANSFER IN BAYONET-TYPE TUBES

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ABSTRACT

The heat transfer with a bayonet-type tube is investigated for the cases where the circulating fluid may be hotter or colder than the system's environment and where the fluid may enter the inner or outer passages. It is shown that most heat is transferred if the inner tube is thermally insulated.

NOMENCLATURE

A_o = Circulating fluid temperature difference between inlet and outlet for $N = 0$

A_n = Same as A_o except $N \neq 0$

c = Specific heat of circulating fluid at constant pressure, B $lb^{-1}F^{-1}$

C_1 = Circumference of outer tube, ft

C_2 = Circumference of inner tube, ft

D = Differential operator $= \frac{d}{dx}$

E = wc = Water equivalent, B $hr^{-1}F^{-1}$

L = Length of surface, ft

m_1, m_2, m_3, m_4 = Roots of an equation, ft^{-1}

M = C_1U_1/E, ft^{-1}

N = C_2U_2/E, ft^{-1}
P, P_1 = Arbitrary constants
q = heat transferred, B hr^{-1}
Q, Q_1 = Arbitrary constants
R = Ratio, A_o/A_n, dimensionless
t = Temperature of system environment, °F
t_1 = Temperature of circulating fluid along inlet passage, °F
t_2 = Temperature of circulating fluid along outlet passage, °F
t_i = Initial temperature of circulating fluid, °F
t_o = Exit temperature of circulating fluid, °F
t_L = Temperature of circulating fluid at $x = L$
U_1 = Overall transmittance based on C_1, B $hr^{-1}ft^{-2}F^{-1}$
U_2 = Overall transmittance based on C_2, B $hr^{-1}ft^{-2}F^{-1}$
w = Weight of circulating fluid, lbs hr^{-1}
x = Arbitrary distance along surface, ft
x_m = Place at which a maximum or minimum temperature occurs, ft
θ_1 = $t - t_1$ if circulating fluid is colder than system's environment, F
= $t_1 - t$ if circulating fluid is hotter than system's environment, F
θ_2 = $t - t_2$ if circulating fluid is colder than system's environment, F
= $t_2 - t$ if circulating fluid is hotter than system's environment, F
θ_i = $t - t_i$ if circulating fluid is colder than system's environment, F
= $t_i - t$ if circulating fluid is hotter than system's environment, F
θ_o = $t - t_o$ if circulating fluid is colder than system's environment, F
= $t_o - t$ if circulating fluid is hotter than system's environment, F
θ_L = $t - t_L$ if circulating fluid is colder than system's environment, F
= $t_L - t$ if circulating fluid is hotter than system's environment, F

The present investigation is concerned with the heat transfer between a fluid circulating inside a bayonet-type tube and a fluid passing over the outside of the tube. The tube assembly is considered to consist of an inner and outer tube so that the circulating fluid passes through a circular passage, and then through an annular passage or vice versa. The analysis is extended to four cases: namely (I) the circulating fluid is heated and enters the inner passage, (II) the circulating fluid is heated and enters the annular passage, (III) the circulating fluid is cooled and enters the circular passage, and (IV) the circulating fluid is cooled and enters the annular passage.

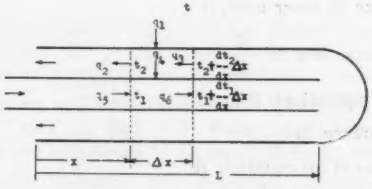

Figure 1. Conditions for case 1

Case I will be considered in detail and is shown in Figure 1. The circulating fluid enters the inner tube at temperature t_i reaches temperature t_L at the end and after passing through the annulus formed by the inner and outer tubes has a temperautre t_o. It is assumed that $t > t_i$, that the thermal conductivity of the materials of the inner and outer tube is infinitely large compared to the surface film conductances, that no heat is transferred to the circulating fluid during direction reversal at the end, that the over-all transmittance with respect to each surface is constant, and that the circulating fluid does not change phase.

With these assumptions, the temperature distribution in the passages, as derived in Appendix I, is given as follows:

$$\frac{\theta_1}{\theta_i} = \frac{m_1 e^{m_1 L + m_2 x} - m_2 e^{m_2 L + m_1 x}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \tag{1}$$

and

$$\frac{\theta_2}{\theta_i} = \frac{m_1 e^{m_2 L + m_1 x} - m_2 e^{m_1 L + m_2 x}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \tag{2}$$

where

$$m_1 = \frac{M}{2}\left(1 + \sqrt{1 + \frac{4N}{M}}\right)$$

$$m_2 = \frac{M}{2}\left(1 - \sqrt{1 + \frac{4N}{M}}\right)$$

$$M = \frac{C_1 U_1}{E}$$

$$N = \frac{C_2 U_2}{E}$$

At $x = 0$, Equation (1) yields

$$\left[\frac{\theta_1}{\theta_i}\right]_{x=0} = \frac{\theta_i}{\theta_i} = 1$$

and Equation (2) yields

$$\left[\frac{\theta_2}{\theta_i}\right]_{x=0} = \frac{\theta_o}{\theta_i} = \frac{m_1 e^{m_2 L} - m_2 e^{m_1 L}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \tag{3}$$

from which

$$\frac{\theta_i - \theta_o}{\theta_i} = \frac{(m_1 + m_2)\left(e^{m_1 L} - e^{m_2 L}\right)}{m_1 e^{m_1 L} - m_2 e^{m_2 L}}$$

Substitution of the values for m_1 and m_2 and introduction of the hyperbolic functions yields (Equation III, Appendix II)

$$\frac{\theta_i - \theta_o}{\theta_i} = \frac{2 \tanh\left(\frac{ML}{2}\sqrt{1+\frac{4N}{M}}\right)}{\sqrt{1+\frac{4N}{M}} + \tanh\left(\frac{ML}{2}\sqrt{1+\frac{4N}{M}}\right)} \tag{4}$$

The circulating fluid temperature rise is given by

$$\theta_i \left[\frac{\theta_i}{\theta_i} - \frac{\theta_o}{\theta_i}\right] = \theta_i - \theta_o \text{ and the heat transferred q is given by}$$

$$q = E\ (t_o - t_i) = E\ (\theta_i - \theta_o). \tag{5}$$

The temperature t_L is found by putting $x = L$ into Equations (1) or (2) yielding

$$\frac{\theta_L}{\theta_i} = \frac{m_1 e^{L(m_1+m_2)} - m_2 e^{L(m_1+m_2)}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \tag{6}$$

If Equations (1) and (2) are differentiated with respect to x, then

$$\frac{\theta'_1}{\theta_i} = \frac{m_1 m_2 e^{m_1 L + m_2 x} - m_1 m_2 e^{m_2 L + m_1 x}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \tag{7}$$

and

$$\frac{\theta'_2}{\theta_i} = \frac{m_1^2 e^{m_2 L + m_1 x} - m_2^2 e^{m_1 L + m_2 x}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \tag{8}$$

If Equation (7) is equated to zero it is seen that the temperature of the fluid inside the circular passage has reached a maximum at $x = L$. Similarly by Equation (8) the temperature of the fluid in the annulus also reaches a maximum and is located by

$$x_m = L - \frac{\ln_e\left(\frac{m_1^2}{m_2^2}\right)}{m_1 - m_2} \tag{9}$$

Since $m_1 - m_2$ is positive, and $\ln_e\left(\frac{m_1}{m_2}\right)^2$ is positive, it is seen that $x_m < L$ and may even be negative depending upon M and N.

As a consequence of this result, it is desirable to determine if there may be a place where $\theta_1 - \theta_2$ is a maximum because such a condition could be the most favorable for design purposes. The requirement that $\theta_1 - \theta_2$ have a maximum or a minimum is given by $\theta'_1 - \theta'_2 = 0$; or by utilizing Equations (7) and (8), there results:

$$m_2 e^{m_1 L + m_2 x} - m_1 e^{m_2 L + m_1 x} = 0 \qquad (10)$$

This result shows that a maximum does not exist, hence there is no most favorable analytical length.

A last consideration may be made if the inner tube is a thermal insulator. In such a case $N = 0$, hence $m_2 = 0$, $m_1 = M$ and Equation (1) becomes

$$\frac{\theta_1}{\theta_i} = 1 \qquad (11)$$

Equation (2) becomes

$$\frac{\theta_2}{\theta_i} = e^{-M(L-x)} \qquad (12)$$

and $t_o - t_i = \theta_i \left(1 - e^{-ML} \right)$, for $N = 0$. (13)

It is shown in Appendix II, however, that $(t_o - t_i)_{N=0} > (t_o - t_i)_{N \neq 0}$, which means that most heat is transferred when the inner tube has zero conductance. The condition of zero conductance may be approached in practice by choosing flow conditions and materials so that U_2 is small.

Investigation of Case II (Fig. 2) yields temperature equations as follows:

$$\frac{\theta_1}{\theta_i} = \frac{m_1 e^{-m_2 L - m_1 x} - m_2 e^{-m_1 L - m_2 x}}{m_1 e^{-m_2 L} - m_2 e^{-m_1 L}} \quad \text{and} \qquad (14)$$

$$\frac{\theta_2}{\theta_i} = \frac{m_1 e^{-m_1 L - m_2 x} - m_2 e^{-m_2 L - m_1 x}}{m_1 e^{-m_2 L} - m_2 e^{-m_1 L}} \qquad (15)$$

where m_1 and m_2 are as before.

Differentiation of Equation (14) shows that the temperature of the fluid in the annulus reaches a maximum at

$$x_m = L + \frac{1}{m_1 - m_2} \ln_e \left(\frac{m_1}{m_2} \right)^2 \qquad (16)$$

which is greater than L, hence is not obtained within the tube system.

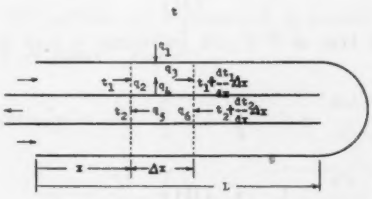

Figure 2. Conditions for case II

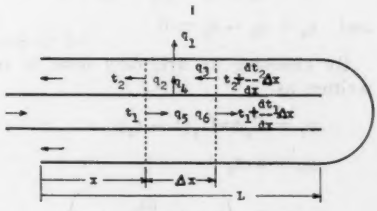

Figure 3. Conditions for case III

Differentiation of Equation (15) shows that the fluid temperature reaches a maximum at $x = L$.

As in the preceding case, the difference between the circulating fluid temperatures does not reach a maximum at any place and there is no most favorable analytical length.

The procedure used to arrive at Equation (4) may be used with Equations (14) and (15) to yield

$$\frac{\theta_i - \theta_o}{\theta_i} = \frac{2 \tanh \left(\frac{ML}{2} \sqrt{1 + \frac{4N}{M}} \right)}{\sqrt{1 + \frac{4N}{M}} + \tanh \left(\frac{ML}{2} \sqrt{1 + \frac{4N}{M}} \right)} \qquad (17)$$

It is seen that Equations (4) and (17) are identical, hence the heat transferred is independent of the manner of introducing the circulating fluid provided M and N are not affected.

Analysis of conditions governing Cases III (Fig. 3) and IV shows that the equations of Case I apply to Case III and that equations of Case II apply to Case IV, if $\theta_1 = t_1 - t$, $\theta_2 = t_1 - t$, $\theta_i = t_i - t$, and $\theta_o = t_o - t$, respectively; and that minimum temperatures occur in Cases III and IV instead of the maxima.

Summary and Conclusions

1. Equations are presented for the temperature distribution of a circulating fluid passing through a bayonet-type tube.

2. Maximum or minimum temperatures of the fluid may occur within the system.

3. It is shown that most heat is transferred if the inner tube is a thermal insulator.

Appendix I

Case I—*Heating a circulating fluid entering the inner or circular passage.*

With the notation shown in Figure 1, heat balances may be made for the two portions of the fluid as follows:

$$q_1 + q_3 + q_5 - q_6 - q_2 = 0 \qquad (I)$$

and $$q_4 + q_5 - q_6 = 0 \qquad (II)$$

By choosing an arbitrary base of zero heat at 0°F, the individual q may be written as:

$$q_1 = C_1 \Delta x U_1 (t - t_2)$$

$$q_2 = wct_2$$

$$q_3 = wc \left(t_2 + \frac{dt_2}{dx} \Delta x \right) \qquad (III)$$

$$q_4 = C_2 \Delta x U_2 (t_2 - t_1)$$

$$q_5 = wct_1$$

$$q_6 = wc \left(t_1 + \frac{dt_1}{dx} \Delta x \right)$$

Substitution of Equations III into Equations I and II yields a system of equations as:

$$C_1 U_1 (t - t_2) - wc \frac{dt_1}{dx} + wc \frac{dt_2}{dx} = 0 \qquad \text{(IV)}$$

and $$C_2 U_2 (t_2 - t_1) - wc \frac{dt_1}{dx} = 0 \qquad \text{(V)}$$

The product wc is the water equivalent E of the circulating fluid. Ratios may be defined as $M = C_1 U_1 / E$ and $N = C_2 U_2 / E$ and noting that $t - t_2 = \theta_2$, $t - t_1 = \theta_1$, and $t_2 - t_1 = \theta_1 - \theta_2$, therefore

$$\frac{dt_1}{dx} = - \frac{d\theta_1}{dx}$$

and $$\frac{dt_2}{dx} = - \frac{d\theta_2}{dx} \qquad \text{(VII)}$$

then Equations IV and V may be written as:

$$\frac{d\theta_1}{dx} - \frac{d\theta_2}{dx} + M\theta_2 = 0$$

$$\frac{d\theta_1}{dx} + N\theta_1 - N\theta_2 = 0$$

which become in operational notation, $\left(D = \frac{d}{dx} \right)$,

$$D\theta_1 - (D - M)\theta_2 = 0 \qquad \text{(VIII)}$$

$$(D + N)\theta_1 - N\theta_2 = 0 \qquad \text{(IX)}$$

If Equation VIII is multiplied by N and Equation IX is operated upon by $-(D - M)$, then θ_2 and its derivatives may be eliminated yielding:

$$(D^2 - DM - NM)\theta_1 = 0 \qquad \text{(X)}$$

The solution of Equation X is readily seen to be

$$\theta_1 = Pe^{m_1 x} + Qe^{m_2 x} \qquad \text{(XI)}$$

where $$m_1 = \frac{M}{2} \left(1 + \sqrt{1 + \frac{4N}{M}} \right)$$

$$m_2 = \frac{M}{2} \left(1 - \sqrt{1 + \frac{4N}{M}} \right)$$

P, Q, are arbitrary constants to be evaluated.

Substitution of θ_1 into Equation IX and solving for θ_2 yields

$$\theta_2 = P\left(1 + \frac{m_1}{N}\right)e^{m_1 x} + Q\left(1 + \frac{m_2}{N}\right)e^{m_2 x}$$

The values of M and N may be expressed in terms of m_1 and m_2 from which $m_1 + m_2 = M$

and

$$-\frac{m_1 m_2}{m_1 + m_2} = N$$

so that $\theta_2 = -P\frac{m_1}{m_2}e^{m_1 x} - Q\frac{m_2}{m_1}e^{m_2 x}$ (XII)

The boundary conditions for the system of equations are:

(a) at $x = 0$, $\theta_1 = \theta_i$

(b) at $x = L$, $\theta_1 = \theta_2$

From boundary condition (a):

$\theta_i = P + Q$

From boundary condition (b):

$0 = Pm_1 e^{m_1 L} + Qm_2 e^{m_2 L}$

These equations may be solved for P and Q to yield

$$P = -\frac{\theta_i m_2 e^{m_2 L}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}}$$

and $$Q = \frac{\theta_i m_1 e^{m_1 L}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}}$$

so that

$$\frac{\theta_1}{\theta_i} = \frac{m_1 e^{m_1 L + m_2 x} - m_2 e^{m_2 L + m_1 x}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \quad (1)$$

$$\frac{\theta_2}{\theta_i} = \frac{m_1 e^{m_2 L + m_1 x} - m_2 e^{m_1 L + m_2 x}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \quad (2)$$

Case II—*Heating a circulating fluid entering the annular passage.*

With the notation of Figure 2, heat balances may be made as follows:

$q_1 + q_2 + q_6 - q_3 - q_5 = 0$

and $q_6 - q_5 - q_4 = 0$

With substitutions similar to those of Case I, the resulting system of equations is as follows:

$$(D + M)\ \theta_1 - D\theta_2 = 0$$

$$N\theta_1 + (D - N)\ \theta_2 = 0$$

Elimination of θ_1 and its derivatives yields

$(D^2 + DM - MN)\ \theta_2 = 0$ so that

$$\theta_2 = P_1 e^{m_3 x} + Q_1 e^{m_4 x} \text{ where}$$

$$m_3 = -\frac{M}{2}\left(1 - \sqrt{1 + \frac{4N}{M}}\right)$$

$$m_4 = -\frac{M}{2}\left(1 + \sqrt{1 + \frac{4N}{M}}\right)$$

But $m_3 = -m_2$ and $m_4 = -m_1$

so that $\theta_2 = P_1 e^{-m_2 x} + Q_1 e^{-m_1 x}$ in terms of previous results.

Solution for θ_1 yields:

$$\theta_1 = -P\ \frac{m_2}{m_1} e^{-m_2 x} - Q\ \frac{m_1}{m_2} e^{-m_1 x}$$

The boundary conditions are:

(a) at $x = 0$, $\theta_1 = \theta_1$

(b) at $x = L$, $\theta_1 = \theta_2$

so that $\theta_1 = P_1 + Q_1$

and $0 = P_1 m_2 e^{-m_2 L} + Q_1 m_1 e^{-m_1 L}$

These last equations yield

$$P_1 = \frac{\theta_1 m_1 e^{-m_1 L}}{m_1 e^{-m_1 L} - m_2 e^{-m_2 L}}$$

and $$Q_1 = -\frac{\theta_1 m_2 e^{-m_2 L}}{m_1 e^{-m_1 L} - m_2 e^{-m_2 L}}$$

from which

$$\frac{\theta_1}{\theta_1} = \frac{m_1 e^{-m_2 L - m_1 x} - m_2 e^{-m_1 L - m_2 x}}{m_1 e^{-m_1 L} - m_2 e^{-m_2 L}}$$

$$\text{and } \frac{\theta_2}{\theta_1} = \frac{m_1 e^{-m_1 L - m_2 x} - m_2 e^{-m_2 L - m_1 x}}{m_1 e^{-m_1 L} - m_2 e^{-m_2 L}}$$

Case III—*Circulating a hot fluid entering the inner passage.*

The notation is shown in Figure 3, and the heat balances are:

$$q_3 + q_5 - q_6 - q_2 - q_1 = 0$$

$$\text{and } q_1 - q_6 - q_4 = 0$$

In this case $\theta_1 = t_1 - t$, $\theta_2 = t_2 - t$, $\theta_i = t_i - t$, and $\theta_o = t_o - t$ so that $\frac{dt_1}{dx} = \frac{d\theta_1}{dx}$ and $\frac{dt_2}{dx} = \frac{d\theta_2}{dx}$. With these relations in mind and with other terms as before, there results a system of equations as:

$$(D - M)\theta_2 - D\theta_1 = 0$$

$$N\theta_2 - (D + N)\theta_1 = 0$$

from which

$$(D^2 - DM - MN)\theta_1 = 0$$

It is seen that this last equation is identical to Equation X, and that the boundary conditions, namely (a) at $x = 0$, $\theta_1 = \theta_i$ and (b) at $x = L$, $\theta_1 = \theta_2$, are also the same as for Case I. Therefore, the equations for temperature difference distribution are the same.

Investigation of Case IV yields results that compare with Case II as has been shown to occur with Cases I and III.

Appendix II

To prove that $(t_o - t_i)_{N=0} > (t_o - t_i)_{N \neq 0}$ for Case I,

Let $A_o = t_o - t_i$ for $N = 0$ and $A_n = t_o - t_i$ for $N \neq 0$.

then $A_o = \theta_i (1 - e^{-ML})$ (I)

and

$$A_n = \theta_i \left[1 - \frac{m_1 e^{m_2 L} - m_2 e^{m_1 L}}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \right]$$

$$= \theta_i \frac{(m_1 + m_2)\left(e^{m_1 L} - e^{m_2 L}\right)}{m_1 e^{m_1 L} - m_2 e^{m_2 L}} \qquad \text{(II)}$$

If the values for m_1 and m_2 are substituted into Equation II, there results:

$$A_n = \theta_i \frac{2\,(e^{FG} - e^{-FG})}{e^{FG} - e^{-FG} + G(e^{FG} + e^{-FG})}$$

where $F = \frac{ML}{2}$

$$G = \sqrt{1 + \frac{4N}{M}}$$

simplification and substitution yields:

$$A_n = \theta_i \frac{2 \sinh \frac{ML}{2}\sqrt{1+\frac{4N}{M}}}{\sinh \frac{ML}{2}\sqrt{1+\frac{4N}{M}} + \sqrt{1+\frac{4N}{M}} \cosh \frac{ML}{2}\sqrt{1+\frac{4N}{M}}}$$

$$= \theta_i \frac{2 \tanh \frac{ML}{2}\sqrt{1+\frac{4N}{M}}}{\left(\tanh \frac{ML}{2}\sqrt{1+\frac{4N}{M}}\right) + \sqrt{1+\frac{4N}{M}}} \quad \text{(III)}$$

where tanh symbolizes the hyperbolic tangent.

Equation I may be put into similar form by letting $N = 0$ in Equation III yielding:

$$A_o = \theta_i \frac{2 \tanh \frac{ML}{2}}{\left(\tanh \frac{ML}{2}\right) + 1}$$

Form the ratio:

$$\frac{A_o}{A_n} = \left[\frac{\tanh \frac{ML}{2}}{\left(\tanh \frac{ML}{2}\right) + 1}\right]\left[\frac{\left(\tanh \frac{ML}{2}\sqrt{1+\frac{4N}{M}}\right) + \sqrt{1+\frac{4N}{N}}}{\tanh \frac{ML}{2}\sqrt{1+\frac{4N}{N}}}\right]$$

$$= \frac{\left(\tanh \frac{ML}{2}\tanh \frac{ML}{2}\sqrt{1+\frac{4N}{M}}\right) + \sqrt{1+\frac{4N}{M}}\tanh \frac{ML}{2}}{\left(\tanh \frac{ML}{2}\tanh \frac{ML}{2}\sqrt{1+\frac{4N}{M}}\right) + \tanh \frac{ML}{2}\sqrt{1+\frac{4N}{M}}} \quad \text{(IV)}$$

Equation IV is of the form:

$$R = \frac{\tanh F \tanh FG + G \tanh F}{\tanh F \tanh FG + \tanh FG} \text{ where } G > 1, F > 0.$$

Since $G > 1$, G tanh F is always greater than tanh FG, therefore $R > 1$, hence $A_o > A_n$.

Similar reasoning is used to establish that the heat transfer is improved for the other cases if the inner tube is a thermal insulator.

GEAR MEASURING EQUIPMENT USED BY THE BUREAU OF SHIPS U. S. NAVY

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INTRODUCTION

The development and application of new materials and designs have played an important part in the improved gearing now being used in propulsion and auxiliary drives on naval vessels. However, materials and designs have been only partially responsible for the outstanding achievements in this field. The *full load* testing of these gears has been entirely responsible for proving the materials and designs. The testing of propulsion gears at full load and speed has been accomplished by the Bureau of Ships at the U.S. Naval Boiler and Turbine Laboratory in Philadelphia* and additional test facilities have been erected at the U.S. Naval Engineering Experiment Station, Annapolis, Maryland.

An essential step in testing reduction gears is the determination of the accuracy of the gear geometry. The American Gear Manufacturers Association has long recognized the importance of gear accuracy and has established a series of standards for various classes of gears, including master gears. Gears now being used in naval service far exceed the American Gear Manufacturers Association Standards for Class 4 gears (AGMA Standard 231.01, 232.01 and 233.01 of May 1946 defines Class 4 gears as those with pitch line velocities exceeding 4,000 feet per minute. The accuracy of Class 4 exceeds that for

* "Marine Propulsion—Gear Testing at the Naval Boiler and Turbine Laboratory," by CDR IVAN MONK, USN, Trans. of the A.S.M.E., Vol. 71, July 1945, pp. 487-499.

Official U. S. Navy photograph.

FIG. 1—General view of gear measuring laboratory at the U. S. Naval Boiler and Turbine Laboratory.

Classes 1, 2 and 3). Gear measuring equipment has been installed, in each of the activities mentioned above. The measuring equipment at these test facilities has been housed in rooms set aside for inspection work. These rooms are air conditioned with both temperature and humidity control to protect the instruments from dirt and moisture. The gear measuring instruments now employed for gear inspection at the Naval Boiler and Turbine Laboratory and the Engineering Experiment Station will be described in the following paragraphs.

MEASURING LABORATORIES

The gear measuring room at the U.S. Naval Boiler and Turbine Laboratory is shown in Fig. 1. The room can be entered only through a double door which aids in maintaining uniform temperatures and cleanliness. The measuring equipment in Fig. 1 includes lead, involute, pitch and concentricity checkers. The hoist and overhead trolley, visible in Fig. 1, is utilized in placing gears in the measuring equipment. The hoist is an indispensable item since many of the

Official U. S. Navy photograph.

FIG. 2—Northwest corner of gear measuring laboratory at the U. S. Naval Engineering Experiment Station.

gear elements weigh up to 750 pounds. The gear measuring laboratory at the U.S. Engineering Experiment Station is shown in Fig. 2. The machines shown are involute, concentricity, automatic reccrder, and lead checker. This laboratory is also equipped with a double door entry and overhead host.

CLASSIFICATION OF INSTRUMENTS

The gear measuring instruments used by these activities are classified as *portable* and *fixed* types. The *fixed* types are heavy and rugged in construction. They are permanently set on concrete foundations and all gears are brought into the measuring laboratory for checking on these instruments. They include involute, lead, base pitch and space checkers, a gear rolling machine and a combination space, involute, helix, alignment and surface roughness checker.

The *portable* units are of such size and construction that they can be moved from one location to another by hand. Use of the portable type equipment permits inspection of gears during various phases of a test program without the necessity of dismantling and transporting to the measuring laboratory. The portable units include involute profile, lead, and base pitch and space checkers.

SUMMARY OF INSTRUMENTS

Since the work of the Naval Boiler and Turbine Laboratory concerns gears in sizes ranging from auxiliary to propulsion units it has a greater selection of gear measuring equipment. The instruments now in use at this activity include:

1. Lead checker (fixed).
2. Rolling machine (fixed).
3. Involute profile checker (fixed).
4. Base pitch and space checker (fixed).
5. Automatic recorder for above units (portable).

6. Combination involute, alignment and helix, concentricity and surface finish checker (fixed).
7. Pitch measuring instrument, external (portable).
8. Pitch measuring instrument, internal (portable).
9. Helix angle checker (portable).

The Engineering Experiment Station is primarily concerned with testing of reduction gears in sizes ranging up to 25 inch diameter. The gear measuring equipment now employed at this facility includes the following:

1. Lead checker (fixed).
2. Rolling machine (fixed).
3. Involute profile checker (fixed).
4. Base pitch and space checker (fixed).
5. Automatic recorder for above units (portable).
6. Pitch measuring instrument, external (portable).

DESCRIPTION OF INSTRUMENTS

Gear lead checker. This machine, fixed type, Fig. 3, manufactured by Michigan Tool Company, permits lead checks, from zero to infinity, on gears of any diametral pitch. It is of the horizontal type, consisting of a transverse table carrying the sine bar and a longitudinal table supporting the indicator.

Official U. S. Navy photograph.

FIG. 3—Gear lead checking machine, Michigan Tool Co., with test gear and automatic recorder.

The tables are so arranged that the sine bar table reciprocates crosswise as the longitudinal table moves lengthwise, parallel to the axis of the gear being checked. The sine bar table, when moved back and forth, rotates the spindle on which the gear is mounted by means of a friction bar and roll.

The spindles supporting the gear are mounted in pre-loaded bearings. The sine bar table and the yoke over the bar which transmits motion to the indicator table are mounted on ball ways to assure uniform motion. Gears weighing up to 750 pounds may be checked in this machine.

This machine will accommodate gears with the following specifications:

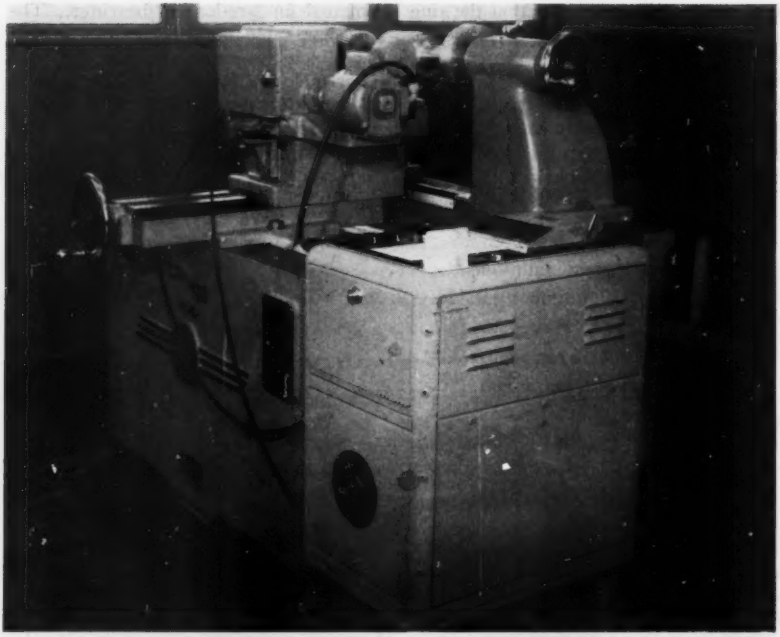
Diametral pitch	No limit
Diameter, maximum outside	30 in.
Diameter, minimum outside	2 in.
Lead	0 to infinity
Distance between centers	48 in.
Weight gear, maximum	750 lbs.
Machine dimensions	
Width	83 in.
Depth	38 in.
Height	55 in.

The automatic checking recorder can be attached to the lead checker so the results of measurements may be recorded for study.

Gear rolling machine. This machine, fixed type, Fig. 4, manufactured by Michigan Tool Company, provides a check of composite errors of tooth profile, tooth spacing, tooth interference and concentricity. The gear to be checked is rolled in contact with a master gear. The two gears are held in contact by spring pressure. The master gear is driven by an electric motor. As the gears are rolled together the combined effect of inaccuracies of profile, spacing, interference and concentricity are indicated by a change in the center distance between the master and test gear. This variation in center distance can be read on the dial indicator or recorded on the automatic chart recorder, shown at right in Fig. 4. The rolling machine will check gears as follows:

Diametral pitch	No limit
Diameter, maximum outside	30 in.
Diameter, minimum outside	2 in.
Length between centers	36 in.
Weight gear, maximum	750 lbs.
Machine dimensions	
Width	69½ in.
Depth	45 in.
Height	49 in.

Involute profile checker. This machine, fixed type, Fig. 5, manufactured by Illinois Tool Works, permits measurement of deviations, planned or otherwise, from the true involute profile. The accuracy and ability of the machine to consistently repeat readings has been well demonstrated by each of the gear



Official U. S. Navy photograph.

FIG. 4—Gear rolling machine, Michigan Tool Co., with test gear and automatic recorder.

test facilities. The automatic recorder can also be used with this machine.

Gears of the following sizes can be checked in this machine:

Diameter, maximum outside	36 in.
Distance between centers, maximum	36 in.
Weight of gear, maximum	750 lbs.
Machine dimensions	
Width	54 in.
Depth	23½ in.
Height	87 in.

The automatic recorder is shown connected to the involute checker in Fig. 5.

Pitch and space checker. Normal pitch and space measuring can be accomplished with this machine, fixed type, Fig. 6, manufactured by Illinois Tool Works. The automatic recorder can be used with this machine. This machine will accommodate gears as follows:

Diameter, maximum	30 in.
Distance between centers, maximum	36 in.
Weight of gear, maximum	750 lbs.

Machine dimensions

Width	66 in.
Depth	36 in.
Height	56 in.

Automatic checking recorder. This electrically driven recorder, portable, Figs. 3, 4, and 5, manufactured by Physicists Research Company, operates on 220-volt 60-cycle power. The unit is well mounted and can be easily moved to any desired area in the gear measuring room. The recorder can be used on any one of the four fixed-type machines mentioned above. Motion of the stylus finger on the measuring machines is transferred to the chart through a converter. Magnification between the stylus movement and the inking pen is 600X. The chart is printed to read in one-ten thousandths of an inch. The range covered by the chart is ± 0.002 in, with the zero at the center. An involute chart of five gear teeth is shown in Fig. 7. This chart is from the Physicists Research automatic recorder and the Illinois Tool Works involute checker described above.

Official U. S. Navy photograph.

FIG. 5—Involute profile measuring machine, Illinois Tool Works.

Combination involute, alignment, helix, concentricity and surface finish checker. This machine, fixed type, Fig. 8, manufactured by the Maag Company, Ltd., Zurich, Switzerland, combines a number of features into a single unit. Measurement and recording of involute, tooth alignment, helix, concentricity and surface finish can be accomplished with one positioning of a test gear. Internal gears can be checked with the use of special feeler arms.

The machine is described by the manufacturer as follows:

"The design of the PH-60 instrument comprises a base, housing the driving motor and gear box unit. Upon this

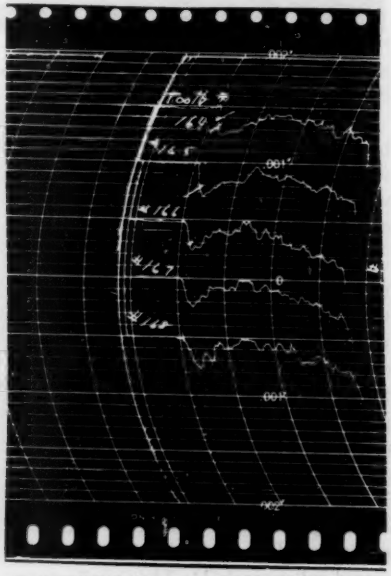
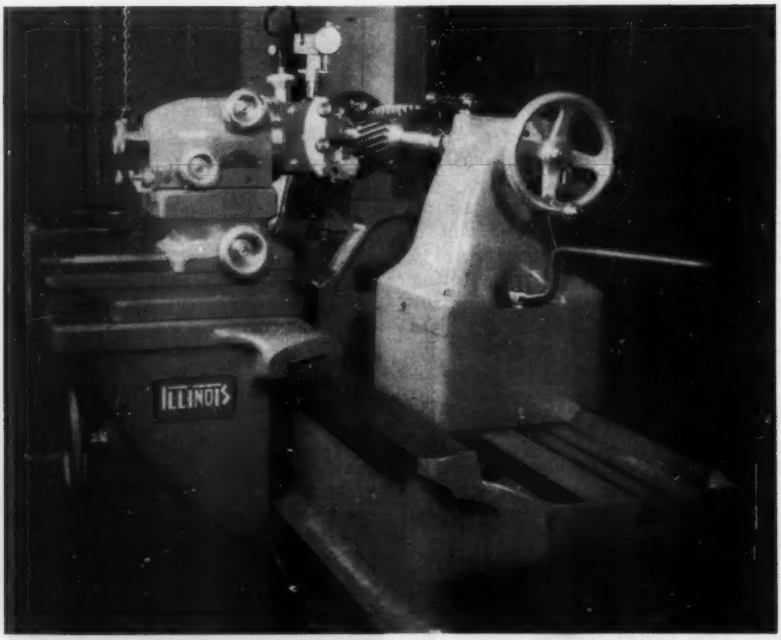


FIG. 7—Involute chart made from the Physicist Research automatic recorder.



Official U. S. Navy photograph.

FIG. 6—Pitch and space measuring machine, Illinois Tool Works, with test gear.

base are mounted the recording mechanism and the cross slides 2 and 4, Fig. 9, which in turn carry the circular disc 7 and the gear to be tested.

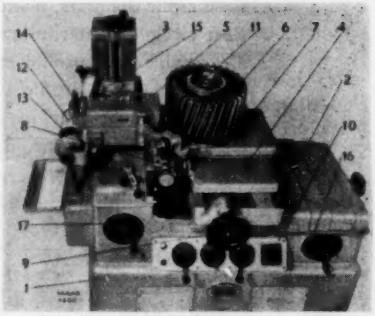
"The recording mechanism 5 has vertical adjustment upon support 3. Below the stylus holder 11 of the recording device is the straight edge 8 against which the base circle disc rolls. When charting a profile the straight edge 8 remains stationary, but when checking a helix angle the straight edge is also moved according to the helix angle of the gear. This movement is actuated through link 21 (Fig. 10) in conjunction with the graduated disc 23, in which is the recessed roller track 22. The spindle upon which disc 23 revolves has on its opposite end a precision circular scale, and by means of microscope 24 the helix angle is set and a direct reading can be taken of any angle that has to be checked. The horizontal movement of slide 4 (Fig. 9) for profile testing is actuated by hand wheel 9. For the movement of the gear and when testing tooth alignment a four-speed motor drive is provided and controlled from a switch built into the instrument bed.

"The recording slide, mounted on the vertical column 3 (Fig. 9) incorporates scale 14 graduated in 0.0001 inch, enabling direct readings to be taken. In addition, a pen recording device 13 indicates by means of a graph 12 any inaccuracies in the gear being checked.

Official U. S. Navy photograph.

FIG. 8—Involute, alignment, helix, concentricity, and surface finish tester Maag Co.

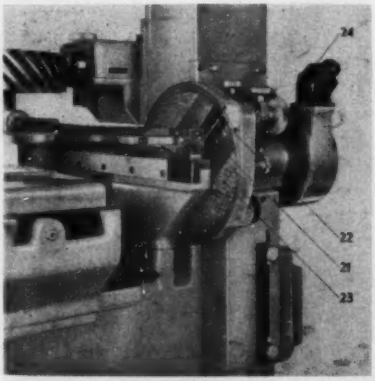
Recordings can be shown in ratios of from 400-1 to 1000-1. For example, a profile deviation of 0.001 inch with the 1000-1 ratio will show on the graph a movement of 0.1 inch."



Photograph courtesy the Maag Co.

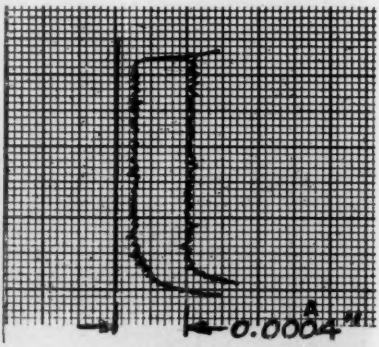
FIG. 9—Gear in position on the Maag PH-60 machine.

Involute charts recorded on the PH-60 machine are shown in Fig. 11. Each division, in a horizontal direction, on the chart represents a movement of the stylus in contact with the gear of 0.00004 in. with a magnification of 1000X. As mentioned above a profile deviation of 0.0001 in. will be indicated on the chart by a movement of 0.1 in. The following information outlines the capacities and principal dimensions of this machine:



Photograph courtesy the Maag Co.

FIG. 10—PH-60. Machine showing microscope, graduated disk and roller track.



Photograph courtesy the Maag Co.

FIG. 11—Involute charts taken on the Maag PH-60 machine.

Base circle diameter, maximum	23 in.
Base circle diameter, minimum	1 in.
Measurable tooth profile, maximum	1.27 D.P.
Measurable tooth profile, minimum	25.40 D.P.
Face width spur gear, maximum	6 in.
Face width helical gear, maximum	
15°	5.75 in.
30°	5.25 in.
45°	4.25 in.
60°	3 in.
Maximum weight gear	330 lbs.
Dimensions of machine	
Length	43 in.
Width	25 in.
Height	61 in.

Circular and normal pitch measuring instrument. The measurement of either circular or normal pitch can be easily accomplished with the checkers, portable types, Figs. 12 and 13, manufactured by the Maag Company. These instruments

Official U. S. Navy photograph.

FIG. 12—Maag Type TMA pitch checking instrument.

are held by the operators in positions shown in Figs. 12 and 13. The TMA instrument, Fig. 12, is for use on external gears. The indicator dial is graduated in 0 0001 in. This instrument is suited for checking in the range 1-12 diametral pitch. The unit measures 4.7 × 5.2 × 1.7 in. and weighs 4.3 pounds.

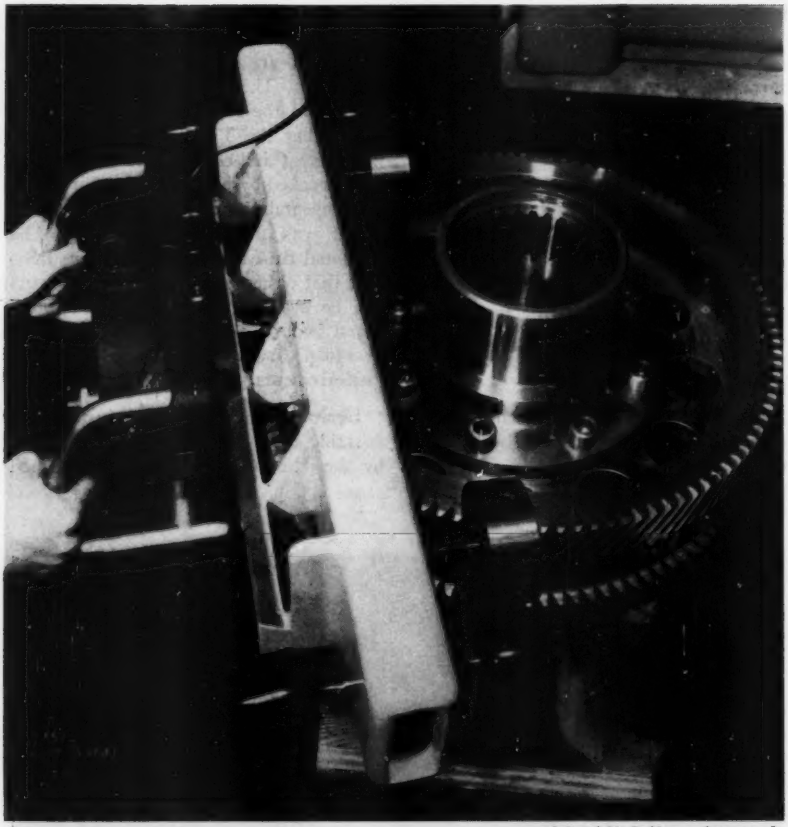
Circular and normal pitch of internal gears are measured with the TMI instrument shown in Fig. 13. The internal pitch checker is used in the range 2-25 diametral pitch. This instrument measures 8.8 × 7.7 × 3.5 in. and weighs 2.5 pounds.

Each of the above portable pitch checking instruments has been used extensively in the inspection of gears. The accuracy of these instruments has been determined by a series of tests conducted at the National Bureau of Standards, U.S. Department of Commerce. In the report of these tests it is stated that the TMA instrument tested will repeat its readings to 0.00002 in. when rocked by hand in either direction. The repeatability of the TMI instrument tested was to about 0.00003 in. The National Bureau of Standards tests indicate that either of the above instruments can be used to determine normal pitch to an accuracy of 0.0001 in. or better, provided care is exercised in taking the measurements.

Helix angle checker. This instrument, portable type, Fig. 14, is manufactured by the Maag Company. It is designed

Official U. S. Navy photograph.

FIG. 13—Maag Type TMI pitch checking instrument for internal gears.



Official U. S. Navy photograph.

FIG. 14—Maag type HM Helix Angle Checking Instrument.

for gears greater than 12 in. diameter. It can be used while gears are in place on hobbing or grinding machines. However, the gear must be positioned with its shaft in a vertical plane. The following data, supplied by the manufacturer, describe the capacities and dimensions of this instrument:

Minimum gear diameter	12 in.
Maximum gear diameter	unlimited
Minimum pitch	13 D.P.
Maximum pitch	1.25 D.P.
Accuracy of reading	+ 12 seconds
Length	13 in.

Width	8.7 in.
Height	10 in.
Weight instrument	24 lbs.
Weight straight edge I	46 lbs.
Weight straight edge II	92 lbs.

The instrument consists of two principal parts, a cast iron straight edge which rests on the side of a gear under test and an attachable unit containing a graduated circle mounted on a shaft terminating in a plane contact surface. This plane contact surface is brought into contact with the flank of a gear tooth and the helix angle of the tooth is read from the graduated circle by means of the optical micrometer.

The circle is graduated every 10 minutes through 360° with each degree line numbered from 0 to 75 in each of four quadrants starting from two zero positions 180° apart, each of which corresponds to a position of the contact face at 90° to the straight edge. The two quadrants adjacent to the zero positions are numbered clockwise and counterclockwise respectively to permit measurement of the tooth flanks on both left and right hand gears. Subdivision of the 10-minute intervals is accomplished by an optical micrometer. This micrometer has 300 graduations numbered clockwise and 300 counterclockwise, each covering a 10-minute interval on the circle.

This instrument was recently calibrated at the National Bureau of Standards. The Bureau of Standards concluded that readings of the circle and optical micrometer could be repeated to ± 3 seconds and the instrument could be used to an accuracy of 6 seconds.

CONCLUSIONS

It is considered that the instruments and machines described in the preceding paragraphs now provide adequate means for determining the accuracy of naval gears. As new and improved instruments become available, the writer feels they will be procured and utilized where needed to aid in producing gearing incorporating the latest materials and designs.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to the Navy Department for permission to publish this paper. The assistance of the Michigan Tool Company, the Illinois Tool Works, and The Maag Wheel Company, Ltd., Zurich, is acknowledged. Mr. J. Cacciola of the U.S. Naval Boiler and Turbine Laboratory and Mr. R. Bartlett of the U.S. Naval Engineering Experiment Station supplied photographs and information on the instruments. Mr. H. J. Ball, Mr. C. C. Atkinson, Commander Ivan Monk and Lt. L. I. Thomas of the Turbine and Gear Branch, Bureau of Ships, provided many valuable suggestions regarding the information presented on the gear measuring equipment now employed by the Bureau of Ships.

MANAGEMENT AND THE PROFESSIONAL EMPLOYEE

ACKNOWLEDGMENT

This article was published in the May-June 1952 issue of the "Harvard Business Review." Its author is PETER F. DRUCKER, Professor of Management, Graduate Business School of New York University.

Professional employees are the fastest growing group in our work population today. At the end of World War II, 75 industrial companies had research laboratories of more than 100 professional people; at that time it was widely believed that this was a wartime phenomenon abetted by excess-profits tax largess. But five years later, at the outbreak of the Korean War, the number of large research laboratories in American industry had almost doubled.

What is perhaps even more significant is that medium-size and even small businesses are beginning to employ professional people in fair numbers. One company with which I am familiar had a single design engineer before World War II. Now it employs eight—and it attributes to this fact its considerable success during the postwar years. For scientific research alone there are now about 3000 laboratories in American industry.

The *scope* of professional employment has also been widening steadily. To the layman—and to a great many businessmen — "professional employee" still means research engineer or chemist. But in addition to the physicists who have entered industry so spectacularly these last few years, business today is employing thousands of biologists, geologists, and other natural scientists, and at least hundreds of economists, statisticians, psychologists—not to mention lawyers.

At the same time professional manpower is the scarcest manpower in this country today—and is likely to continue very scarce for years to come. Korea and the defense program are actually minor factors. The real trouble is the tremendous increase in the demand for professional people both by business and by government, coming just when there is a very sharp dip in the number of men taking professional training as a result of the low birth rates of the 1930's. It is even very doubtful whether our universities have enough capacity to turn out all the professionally trained people our society requires. The well-publicized shortage of medical-school facilities may be only one of many.

In view of this situation, one would expect industry to be doing its best to handle professional manpower efficiently. Yet attitude surveys of professional em-

ployees in industry show their morale to be relatively low; they apparently know little about the businesses with which they are associated, and they complain continually about their "isolation." Also, studies of the work load and organization of professional employee groups indicate a high degree of waste in the use of this high-grade, expensive, and scarce human resource.

DIFFERENCE IN BASIC ATTITUDES

Management can be blamed, if at all, only for insufficient imagination to see the problem for what it is. Actually the underlying difficulties are not of management's making. They lie in the difference in basic attitudes between professional people and the rest of the business organization.

Professional Standards. It is the essence of "professionality" to apply objective standards of craftmanship and accomplishment to one's work, rather than business criteria. All of us have heard sales managers say that they can never get a design out of the engineering department (or other executives commenting about their chemists, physicists, economists, and psychologists): "These people want perfection; they don't care a rap how long it takes, how much it costs, or whether anyone else wants perfection anyway. They always want another four weeks to improve the job just a little more."

Yet even the sales manager, when asked whether he would prefer a design engineer who is satisfied with work that "will get by," will reconsider in a hurry. Some companies, to be sure, want technicians rather than professionals—men who are good and quick at doing the immediate, assigned job and no more. But these companies not only will fail to attract really good men (or will lose them fast if they do get them); they also will deprive themselves of the major contribution that the professional man can make, which springs directly from his objectivity, his standards, his refusal to accept uncritically management's definition of a problem or management's idea of what the result should be. It lies, in other words, precisely in his professional attitude, which is at such variance with the managerial attitude that at times the two appear almost irreconcilable.

Ingrained Working Habits. Another difficulty lies in deeply ingrained working habits—so deeply ingrained as to have become almost a part of the professional man's personality. He has been trained—and rightly so—to work on his own. Every research man, whether chemist or economist, has it hammered into him that he must personally check all the data he uses. I know of a good many lawyers, seniors in big firms, who would never use a case reference turned up by their law clerks without looking up the case themselves. To call the professional man an "individualist" is misleading; he often works extremely well in a team. But he does not, as a rule, take kindly to modern organization — and especially not to large-scale organization. He may be willing, indeed eager, to be a specialist and to leave all but his specialty to others. But in his own field he is apt to insist on having complete control of the entire job.

That is why a distinguished physical chemist I know left an attractive job with a large company—a big laboratory, all the assistants he wanted, a big salary—to go with a small business where laboratory facilities are poor, assistants nonexistent (he has only a girl to clean up), and the salary is quite a bit lower. But now he does the whole job. He sets up his own experiments; he writes up his own notes; he even makes a good many of his own instru-

ments. "I do the entire job now—my way," was the only explanation he could give me for his decision. And while admittedly an extreme case, this is not at all an untypical one.

Self-Contained Logic. Finally, the professional man's logic is such that he has difficulty understanding the businessman's reasoning. For example:

> A few years ago, in 1947, a large company set up an economic and market research department. It took the new department a few years to get started, and up to 1950 it had little to show for the money spent. Yet business was very good. The head of the department as well as the men in it received sizable salary increases every year.
>
> Last year, for the first time, the department produced major results. But 1951 was a poor year for the company. And when the head of the department went to the president with recommendations for raises for the men who had done the big job, he was told that no salary increases would be granted for the time being. This so upset him that he left—to take a professorship at about a third of his salary.
>
> Yet this man is no "ivory-tower academician"; up to this time he had spent most of his working life in big companies. Why did he leave? To him management's action was totally irrational, a sign that it neither cared for his work nor understood it. For "obviously" (he said) the quality of the work done by his men was in no way affected by poor business conditions.

The problem is thus one of basic attitudes. That by itself rules out easy or fast solutions. To make matters still more difficult, the attitudes that cause the difficulties are in themselves desirable. The task is not to change the professional employee's attitudes; indeed, most of whatever changing has to be done will be in traditional business habits and practices. The real task is to find how to use the professional employee effectively *as* a professional.

Fairly extensive experience with professional-employee groups has convinced me that the most practical approach is to identify the points at which friction is most likely to occur in the relationship between business and its professional employees, and then to try to "lubricate" these friction points so that they will cause less trouble, less loss of efficiency. There is no hope of correcting the situation completely, but certain constructive steps can be taken to make it a great deal better than it is in many companies today.

FRICTION POINTS

Close observation of professional personnel generally—and, even more pertinent, of professional and nonprofessional personnel in the same company—shows clearly where the main points of friction are.

The Administrative Process. Professional employees do not fit into the administrative process—and the administrative process does not fit them. In particular, the very concept of "supervision" goes against the grain of professional employees.

In many ways this matter of the "supervision" of professional employees illustrates the entire problem, for it is a good example of the businessman's failure even to realize that the professional employee presents a problem. "Supervision"—both the term and the institution itself—is automatically applied to professional employees because it is the established thing for other employees. Yet not only is it resented by professional people; it is not the appropriate organization pattern for them.

Professional people work as "senior" and "junior" rather than as "boss" and "subordinate." Of course somebody has to be in charge of the project or activity and be responsible for it. But the professional thinks of it as a group project, with each member of the team having independent responsibility clearly vested in him. Thus the superior should be a coordinator or a teacher rather than a supervisor.

Altogether the relationship between the professional man and the administrative process needs rethinking. By and large the better a man is in his profession, the poorer an administrator he is likely to be. And the better a man is professionally, the less respect for administrative work and administrative ability he is likely to have. However, promotions to administrative positions are the only ones as a rule that business has in its power to give. This means that the promotion in a professional work group is likely to go to a man for whose professional abilities his fellow workers have little respect.

A good many companies are becoming aware of this problem today. But they try to solve it by looking for the prodigy; the high-grade professional with administrative abilities and with a liking for administrative work. Though there are such people, they are exceedingly rare. To look for them is simply wasting time in a search for the mythical "philosopher's stone."

Instead we shall have to work out some way to give the senior positions in the professional group to the men who are the leaders in the professional field, regardless of their administrative ability. Where the group is larger, they should be given to men with outstanding ability as teachers—but in all cases the professional reputation and achievement of the man at the top should be the first criterion. The administrative job itself will have to be played down. It might, following the practice of the government, be handed over to an "administrative assistant" who would not have any direct authority over the professional staff. (In all likelihood, though, the administrative assistant, while without prestige, will enjoy more power than he really should have—simply because the professional people will tend to unload administrative work on him.)

Professional Recognition. Closely tied in with the professional employee's attitude toward the administrative process is his dissatisfaction with the lack of professional recognition. Opportunities for such recognition are needed both inside and outside the company.

In every professional-employee work group that I have been able to observe, there were men who enjoyed the greatest respect on the part of their fellow workers—and who were incidentally often of the greatest value to the company—but who preferred to work by themselves and who, in some cases, were actually incapable of working with other people. To promote such a man to a position of command means destroying both him and the job. Not to promote him to a position of recognition and authority, however, will breed real discontent throughout the entire group.

This is not a new problem, though it is a new one for business. Organizations such as the Army or the Catholic Church have been wrestling with it for a long time. Both have succeeded in securing the services of men who may be useful as advisers rather than as administrators by providing independence and recognition in the form of "prestige spots" outside the line of command: for example, positions in the various Papal colleges in Rome or at the Vatican Library and teaching positions in the staff schools of the Armed Forces.

Occasionally a company will do something similar by employing a professional man as "special adviser" or "re-

search consultant," with the prestige and pay of a senior position but without administrative duties. But the practice is still the rare exception—whereas it might have to become fairly routine.

This, however, would solve only the problem of the distinguished senior man. And it is the younger people who, as a rule, complain the most about the "lack of professional recognition." That need can be satisfied only by creating "prestige" positions *outside* the business.

Most businesses employing professional people today permit such outside activities, but very few so far encourage, let alone reward, them. Yet the employee who enjoys standing within his professional brotherhood will not only be a more satisfied employee; he will also have a real incentive to become a more proficient man in his field. And he will attract promising young professional people to the company—no small matter today when professional workers of competence are scarce.

The usual way to encourage such activities is through emphasis on participation in professional societies. This is certainly all to the good. But it is not the only way. Especially for the younger man, part-time teaching is likely to be of greater value. The man who teaches his discipline one evening a week at a good university or engineering school feels professionally recognized. He will have an inducement to perfect himself in his field or at least to stay abreast of developments. If he needs some time off for this teaching, the cost can be charged to public relations. The company will be ahead in the end. Yet today a good many companies still forbid their employees to accept part-time teaching jobs—with the rather silly argument that "the employee should give his entire time and attention to the business that pays him."

Work Assignment. The kind of work business expects from the professional man and, in particular, the way it is assigned represent another major point of friction. Whereas the relationship between professional status and administrative process is likely to be most problematical when there are larger numbers of professional employees, the problem of work assignment is likely to cause the most trouble in the small professional-employee group. For example:

> A small company I know of had a laboratory requiring two first-rate chemists. Working conditions, pay, and opportunities were excellent, and the work itself fascinating. Yet, until recently, no chemist stayed longer than nine months—hardly enough time to get broken in. The trouble lay in the way work was assigned on the basis of immediate production needs as they arose in the plant. Chemist after chemist attempted to point out that these "bugs" are all of one pattern and should be tackled through a long-range, basic research project. But plant management insisted—understandingly, from its point of view—that immediate production problems be tackled as such. As a result, the chemists all felt that they were nothing but "glorified repairmen."

In this case the remedy was simple: to bring the chemists in on the assignment by forming a "research committee" composed of operating vice president, production manager, and senior chemist. Within a few months the committee brought about mutual understanding and a decision to bring in a third chemist to make possible both immediate and long-range work.

But normally things are more complicated and do not permit of so easy a solution. The work of the professional employee must be directly focused on the success of the business—especially in the small company. He is a member of the enterprise, after all, and not a company's philanthropic contribution to the advancement of knowledge. But the work must also make sense within the

framework of a professional discipline. Indeed, the professional employee who becomes disgusted when he is being used as a technician is better than the one who accepts the complete subordination of his craft to business rationale. For the latter becomes a cynical hack and will soon cease to make any contribution to the business—even as a technician.

Personnel Administration. The fourth and final major point of friction is in the matter of personnel administration. The professional employee is singularly unenthusiastic about it; in fact he actively dislikes it.

If there is one most positive conclusion to be drawn from my work with professional employees, it is that personnel administration, with all its policies, techniques, and procedures, must not be applied to the professional group. Whatever it is—salary administration, employment practices, training methods—as it is developed by the "expert" in the personnel department it is unlikely to fit the professional employee. (That "good personnel practices" are so rarely practiced by the personnel departments that preach them is simply added evidence.)

It is not only that personnel practices developed to fit rank-and-file employees (manual or clerical) do not also fit professional employees. Whether they fit or not, the professional employee regards their imposition as the very antithesis of professional status; and there is nothing that he resents more deeply. Conversely, nothing appeals so much to his idea of the status due him as does direct responsibility to work out for himself the personnel practices and procedures that concern him and his group.

I am not saying that he will do a better job than the personnel expert. For instance, he is quite likely—especially if he is an engineer or an economist—to devise the most complicated salary plans. And he may argue for weeks over a minute and totally unimportant point. But the fact still remains that the professional group demands self-government in respect to personnel practices. That business today imposes personnel practices on him is perhaps his greatest grievance.

ISOLATION FROM THE BUSINESS

We have to "professionalize" the professional's job. The better we succeed, however, the more will we aggravate another major problem: the professional employee's isolation from the business. Indeed, if it is the main complaint of the professional employee that he is treated as an employee rather than as a professional, it is the main grievance of management that he does not think of himself as working for the company but rather regards the business as his laboratory, if not his guinea pig.

It is obviously important for the company that its professional people have some understanding of the business and some interest in it. How otherwise would the engineer, biologist, chemist, or economist ever understand why there has to be a deadline, why he has to push this project and drop that, or why his professionally most elegant solutions may not be adapted to the needs of the business?

Integration into the business is equally important to the professional man. He considers himself—rightly—as belonging to the management group. Whether he realizes it or not, he has a strong need to feel that he is connected with the business, that he understands it and can contribute to it—in marked contrast, for instance, to the highly skilled artisan whom, in other matters, the professional man closely resembles.

But few professional employees, in my experience, actually feel that they are part of the business. "We never know what management is after" is a standard complaint. Of course, the lines of communication from management to the professional employee are in no worse shape than those to other groups —probably in better shape, on the whole, than those from top management to middle management in the typical company. But precisely because he is a professional—that is, a highly specialized person and as such tending to be engrossed in his own world—the professional is hard to reach even over a functioning line of communication.

Exposure to Business Facts. The accepted solution for this problem today seems to be the rotation of new professional employees throughout the various departments of the company before their placement in their professional job. I am convinced that this practice does very little good. It certainly does not give the newcomer a view of the business—at least not a lasting one. It only fills him with impatience to get to the job which he wants to do and for which he, rightly, thinks he has been hired. By the time he reaches this final destination, whether as a research engineer, as a biologist, or as a statistician, he has only one desire: never again to have anything to do with those "nonprofessional" people outside his own department. Also the young professional is singularly unreceptive to anything outside and beyond his own specialty. It is only after he has been in professional work for five or ten years that he evinces a desire to know what goes on in the other departments of the company for which he works.

Instead of rotating the juniors we might expose the senior people in the professional group to the facts of business life. They could be brought in on discussions of long-run policy, participate in decisions on the range of products, help to determine production programs, and so on. All this may seem obvious. The fact remains, however, that in far too many companies today, even in companies in which it would be easy to do so, the professional employees are not brought into the normal business decisions—for the very reason which ought to insure their inclusion, namely, that they know nothing about these matters.

We must expect no miracles. The good professional employee will never become a good all-round businessman; if he had abilities or interests in that direction, in all probability he would not have stayed a professional man very long but rather would have drifted into selling, finance, or production. But this is all the more reason for giving him as much of an insight into business as he can possibly acquire.

In the larger companies, of course, direct exposure will be possible only for a few of the professional people. The rest will have to get their knowledge through "formal" communication. Fortunately, the professional employee—so my studies indicate—seems to have the most favorable attitude of all employee groups toward company reports, informative letters from top management, presentations of company figures—even long and weary ones—and so on. He bitterly resents, though, anything that smacks of "popular writing" or "visual presentation" and demands the original version, however difficult and unreadable it may be. More than other groups professional employees demand an opportunity to ask questions and expect long, detailed, and frank answers.

(If you really want to see how complicated people can get, ask a group of your engineers to work up the presentation of your annual report to your engineering department—though you run the grave risk of their finding out to their horror that depreciation figures are metaphysical abstractions rather than what the engineer calls "facts"!)

A better understanding of the business, its organization, its policies, its direction, and its success, will not by itself overcome the discrepancy between business objectives and professional rationality and standards. But precisely because of this discrepancy it is doubly important that the professional employee not feel isolated from the business and uninformed about it.

ECONOMICAL USE OF PROFESSIONALS

In contrast to the other steps I have suggested, one of the most important and most effective contributions to better utilization and greater satisfaction of the professional employee is fairly easy: making sure that professional employees are really used for professional work. Despite the shortage of professional people and their high price, few companies seem to have given much thought to this so far.

The saving that can be made by elimination of unnecessary chores can be substantial. For example:

> One large company employing research engineers, physicists, and chemists just added the equivalent of 80 high-grade research men to its staff—simply by studying the jobs of its research personnel and eliminating from them all clerical chores and all work that could be done by semi-skilled personnel. Almost a full third of the work load of the professional people was found to be within the reach of people who had taken a few science courses in high school or college or who had drawing ability—whereas the work had been done by men with Ph.D. degrees and with 10 or 15 years of specialization in advanced and independent research work.
>
> I found a similar situation in a large chemical laboratory. Again almost a full-third of the work was primarily clerical or beginner's work and required very little knowledge of chemistry.
>
> Or take the example of a small company, employing five research and design engineers. When the company found that it could not, under present shortage conditions, easily hire the three additional research engineers its increased work load seemed to require, it was forced into a study of the work of its existing force. A simple survey brought out the fact that the company could manage without a single additional research engineer if only the existing force concentrated on research and design instead of spending one-third of its time on maintenance, machine repairs, and tool design. What the company needed was one good master mechanic—and getting him solved the problem.

To relieve professional people of all merely clerical or routine work is more than good business. It is also the prerequisite for high morale in the professional organization. Indeed, I am reasonably certain that under present shortage conditions good professional people simply will not stay with a company that expects them to do clerical or routine work. A work-load study is thus the one thing any employer of professional personnel should undertake—and undertake soon.

CONCLUSION

I have a suspicion that some of the difficulties and problems of the professional employee may actually be pretty general difficulties and problems—especially in a society in which the bulk of the citizens are both employees and highly schooled. For instance, "supervision" may well be as troublesome a

concept for other employee groups. Again, I suspect that today's heavy emphasis on administrative ability as *the* executive skill, and hence the primary basis for promotion to executive rank, may be altogether questionable in its wisdom as well as in its morality.

The professional employee may serve only to bring out these general problems—because he is new to being employed and thus critical of things other groups accept as a matter of course; because he has great mobility—even scarcity value today—and thus "doesn't have to take it"; and because he is very, very articulate about his grievances.

The fact remains that these problems do exist in the employment situation of professional people — whether or not they also exist elsewhere. This alone makes them important to management.

There are indications that the growth in the number and in the importance of professional employees will be a major characteristic of the next quarter century of American industrial development, just as the rise in the number and importance of clerical employees characterized the last 25 years. The introduction of electronic "brains," for instance, would bring into industry a whole host of new professional men trained in disciplines of which most businessmen have hardly even heard, such as a symbolical logic. (The fact that electronic "brains" demand such a large number of professionally educated and technically trained men is, incidentally, the reason why I have my doubts about the imminence of the "cybernetic revolution.")

But even without additional growth there are enough professionals employed in American industry today to make it worth while for management to try to do a decent job in handling them and in utilizing their capacity for the good of business and the economy. Or will we again wait—as we did with the manual worker and as we may be doing with the clerical employee—until somebody holds a knife to our throat?

WORLD WAR II SHIPBUILDING AND SHIP REPAIR IN NEW ZEALAND

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is Assistant Supervisor of Shipbuilding, Baltimore, Md. He was commissioned 28 February 1930 as a Lt. (J.G.)—Construction Corps, U. S. Naval Reserve. On 7 October, 1940 he was called to active duty and assigned to the Design Section of the Norfolk Navy Yard. To aid the training of personnel in that rapidly expanding organization, he organized the University of Virginia Norfolk Extension for Naval Architecture, teaching in the evenings for two years. He was next assigned to the Pacific. He holds the Bronze Star Medal. The late King of England appointed him an O.B.E. in recognition of his services as officer in charge of shipbuilding and ship repairs in New Zealand and commanding officer of the U. S. forces in Auckland.

The splendid performance of New Zealand and its cooperation with us are matters of the history of World War II. The association with the people of the Long White Cloud at the time was, and in retrospect is, a source of inspiration of the highest order. In this article, I will attempt to set forth the Shipbuilding and Ship Repair Programs in New Zealand. Recognition should be made, at the outset, of the high tribute paid by the New Zealand newspapers and journals to this work during my stay in their hospitable country.

1. INTRODUCTION

The news of the Japanese attack on Pearl Harbor was received by the New Zealand people on December 8, 1941 with the following principal reactions:

(a) Shock over the extent of our losses, which they believed were much greater than first reported.

(b) That the Japanese displayed stupidity, because any unwillingness in America to participate in the war was dissolved in that instant, and that the industrial and military might of the United States would, with unity of purpose, rise to undreamed of heights.

(c) The realization that although New Zealand was better off in a military sense than it was in September 1939, the outlook was dismal because little had been accomplished to carry the extension of the war into the Pacific. The facts are, briefly, as follows:

(1) In World War I, New Zealand troops displayed unusual gallantry and achieved renown.

(2) The Depression of 1922 resulted in an immediately almost complete elimination of the Defense Forces. Drastic cuts were quickly made in all military expenditures not of immediate necessity.

(3) In 1927, New Zealand undertook to contribute one million pounds towards the construction of the base on Singapore in the belief that it (Singapore) was the Gibraltar of the Pacific and that a powerful British fleet would be based there.

(4) The Depression of 1929 vitiated the small Defense Forces, which had been revived in 1927. In 1932, the financial position was considered so acute that the greater part of the reserve equipment for the Army was sold overseas.

(5) Practically nothing was done from 1929 to 1939 in the direction of National Defense. Orders placed in Britain in 1936 and 1937 for coastal artillery were never fulfilled.

(6) With full knowledge of the situation, the Prime Minister of New Zealand voiced the attitude of his people by pledging on the night of September 3, 1939, "Where the Mother Country goes, we go." It was a repetition of the whole-hearted spirit of participation which existed in 1914.

(7) The Dominion immediately started to raise a complete infantry division for service overseas. The number of men seeking service always exceeded the demand. Volunteers were accepted only for the three Echelons of the Second Division, which later achieved fame in North Africa, Greece, Crete and Italy; for the Navy and for the Air Force. The Defense Act of 1909, which provided for compulsory military training of all men for home defense, was applied with vigor during the summers of 1940 and 1941, by calling certain classes of single men for three months of intensive training, after which they were returned to civil life. Equipment was sadly lacking and hopes for additional material were repeatedly dashed when supplies earmarked for New Zealand were diverted to Russia.

(8) The Air Force made excellent strides, but with obsolete equipment. Air fields were constructed, usually without hard surfaced runways. The turf was soft in wet weather, and for heavy planes a wheels-up landing became necessary. Sea planes could land in Auckland Harbor (base of Tasman Airways and Pan-American), but not in the Wellington area, due to the hazards presented by sea and weather.

(9) The Navy activated its minesweepers and was ready to procure the services of suitable craft and personnel in the Dominion if the situation became more acute. No attempt was made to improve the facilities at the one Navy Yard; HMNZ Dockyard, Devonport, which is across the harbor from Auckland. It might be noted, at this point, that the graving dock in the Dockyard was enlarged later by the U.S. Navy under Reciprocal Aid.

(10) The opinion had prevailed that the United States would defend the Pacific against aggression. The visit of the U.S.S. *Brooklyn*, the U.S.S. *Savannah* and Destroyer Division No. 4 in 1941 did much to confirm that

belief. It was hoped that the inevitable clash with the Japanese would be postponed until after the European War was over.

(11) New Zealand was, and is, primarily an agricultural country. The Dominion has no natural resources of iron, had progressively developed hydro-electric power until it stood between the United States and Germany in power developed per capita and drew upon her coal resources as required, but production line manufacturing remained virtually non-existent. A few assembly plants in certain lines of industry had been operating for a decade or more. Steps had been taken to implement such manufacturing, but New Zealand relied upon open sea lanes for the transportation of machinery and munitions from Britain.

On December 8, 1941, the Dominion was placed on a war basis. The Defense or Territorial Forces were called up for full time duty. Units moved into the defense positions at the principal ports. The First Division occupied North Auckland, the Fourth was stationed in other parts of the North Island and the Fifth in the South Island. B Force in Fiji was increased to a division, and was given the best, and, in some instances all of vital military equipment. This division was subsequently relieved by U.S. Forces. Anti-tank ditches and road blocks were constructed, beaches mined, machine gun emplacements built, air raid precautions taken, private air shelters built, medical stations set up, motor vehicles given to or impressed by the Government, and efforts made to augment the defenses of the ports. An anti-submarine boom was installed in Auckland Harbor. But there were shortages of the most crtical nature in weapons, munitions, and, in fact all war material, which the ingenious improvisation and feverish, yet well planned, activity could not overcome. Lack of roads and mobile equipment would have precluded units from moving quickly to support each other in event of invasion. At this juncture, New Zealand heeded the earnest plea of the United States and Britain, and decided against withdrawing the Second Division from North Africa for home defense. The plans for Auckland to become the Chief Naval Base in the South Pacific Area, the arrival of United States vessels, equipment and personnel in the Area and later, our invasion of Guadacanal heralded the United States as the Savior of New Zealand.

The New Zealand cruisers, *Achilles* and *Leander*, the latter replaced by the *Gambia*, rendered varying types of duty in the Pacific. The Navy also sent valuable small units of corvettes, minesweepers, and motor patrol boats to the New Caledonia and Guadalcanal areas. The first two of the aforementioned cruisers saw action and the Dominion lost the corvette *Moa*.

The Third Division rendered valuable service in New Caledonia, Guadalcanal, the taking of Vella Levella, the seizure of the Treasury Islands and the capture of Green Island. The Division was returned to the Dominion in June 1944. In the early part of the War, the Air Force (R.N.Z.A.F.) sent squadrons of fighters, bombers and reconnaissance planes to the assistance of our forces. At the close of the War, New Zealand air squadrons were assisting the Australian Army at Bougainville and New Guinea.

The returning servicemen from North Africa (for the most part, wounded men), the South Pacific and those discharged from the divisions in New Zealand tended to fill the gaps in farming and industry. The critical situation, which existed on Pearl Harbor Day, brought about the adoption of legislation which placed all men and women under the control of the military or

strict Manpower Boards, in order to provide sufficient personnel for essential military and civilian duties. However, there was a definite shortage of personnel in essential occupations until after VJ Day. New Zealand had always been a producer of foods, particularly meat, on a large scale. The people did not relish the continuance of this role while leaving others to do the fighting, but they were willing to be guided by such men as President Roosevelt and Prime Minister Churchill. The ship repair program, which enjoyed Priority No. 1, and the new ship construction program required the services of the great majority of men who possessed any degree of mechanical skill.

The following statistics are given to further provide a basis of understanding of the situation:

Area: 103,415 sq. miles. Area is about same as state of Colorado.

Population: 1,655,794 on January 1, 1945. Approximately same as state of Maryland.

Principal Cities:

Auckland	Population	256,426
Wellington	Population	175,189
Christchurch	Population	112,525
Dunedin	Population	65,487

Production—Year 1942-43

Value of agricultural production, grand total		$551,900,000
Manufacturing, all kinds		
No. of establishments	6,127	
Total number of employees	114,950	
(Note low average of employees per establishment—N. Z. is a country of small businesses.)		
Salaries and wages paid		$104,800,000
Value of buildings, machinery and plant		$286,900,000
Taxes collected—Year ending Mar. 31, 1943		$ 27,625,000

National Income

Salaries and wages paid (18% of this for manufacturing)	$571,675,000
Social Security Benefits and Pensions (This amount equals 49% of salaries and wages paid in manufacturing)	51,025,000
Company income	132,925,000
Other income of individuals	194,350,000
Total	$949,975,000

Food Supplied to United States Forces in South Pacific 1943-46

Weight: Approx. 440,000 long tons.
Quantity: 25% of total vegetable and apple crop
15% of total meat produced
8% of total dairy products

This food was carried in U.S. Navy reefers and cargo vessels. The carrying of refrigerated products from New Zealand to the islands of the Pacific for our armed forces on tight schedules provided our office with a continuing work load of maintenance, renewal and repair to the propulsion and refrigeration plants of many reefers (most of them being conversions to banana ships and California fishing craft.)

II. NEW ZEALAND SHIPBUILDING PROGRAM

The post war New Zealand official report on shipbuilding is quoted in part as follows:

"It would be wrong to say that ship construction in New Zealand commenced during the last war period. It would be more correct to say that shipbuilding was rejuvenated with a vengeance. Ship construction is not by any means a venture tied to the present century, as in the early days of New Zealand, wherever there was a Kauri forest there was a small shipbuilding effort on wooden vessels. Most of our earlier traders on the coast were built in New Zealand, and later, when good heart Kauri became more scarce, very creditable units were constructed, both in composite design (steel frame and wooden planking) and in all-steel. The best examples of our composite built vessels are the ferry boats of the Ferry Company at Auckland. In 1937 one of the present vehicular ferry boats was constructed with diesel engines. Further south the S.S. *Earnslaw* for Lake Wakatipu was built by Messrs. John McGregor & Co. at Dunedin. The tug *Dunedin* was built by Messrs. Stevenson & Cook at Port Chalmers in 1914, and the present motorship *Hokitika* was built two years later by Messrs. John McGregor & Co. Many other examples could be quoted, but the above are given merely as an indication that small craft have been built in New Zealand right throughout the last century."

Shipbuilding was perhaps carried on effectively to meet the needs of a young and growing country, which was primarily agricultural, but it was actually in a desultory fashion. The country was blessed with the giant Kauri (heart Kauri is one of the best woods in the world for planking vessels) and the native Totara is excellent for sheathing. The native beech is suitable for framing of boats up to 60 feet in length, but the general absence of appropriate New Zealand woods for large and heavy framing led to the adoption of the composite type of construction for larger vessels.

During the war, shipbuilding in New Zealand was under the direction of the Honorable Minister of Marine at first, then as the involvements of procurement, such as steel from Australia, became vital issues, it was placed under the direction of the Honorable Minister of Supply and Munitions, and in late 1942 the appropriate authority for the industry became the Commissioner for Defense Construction, who was given the additional title of Controller of Shipbuilding. Shortly after VJ Day, the Head of the Marine Department became the Controller of Shipbuilding and a rather quick transition was made to a peace time set up, with the Marine Department functioning as it did before the war and working with the War Assets Realization Board in the disposition of surplus property and vessels.

Eventually, three small minesweepers of composite construction, the *Rimu*, *Hinau* and *Manuka*, were completed (after the inception of the American shipbuilding program.) They were constructed on hastily improvised shipways

in Auckland on foreshore sections made available by the Devonport Steam Ferry Company, Ltd. and the Northern Steamship Company, Ltd., by two of the old shipbuilding companies and two engineering firms, which had wide experience in ship repairs. The engines for these vessels were taken from five old condemned vessels in Rotten Row. These three minesweepers were employed until the end of the war. A fourth, the *Tawhai,* was almost completed when the war ended, and was later sold to UNRRA for conversion in Auckland to a trawler.

Nine steel trawlers were also built, seven of them at the plant of Stevenson and Cook, Port Chalmers (Dunedin). Steel was procured in Australia. Boilers were eventually ordered from England and after the first two or three, were delivered in a prefabricated condition, the balance of the work being performed principally by the N. Z. Railway Workshops at Woburn. Engine forgings were ordered from Australia and the firm of A. & G. Price at Thames effectively accomplished most of the work of construction and fabrication of the engines. This program lagged to an excessive extent. It was no sooner under way than the British Navy pressed an order for twelve "Fairmile" patrol vessels for anti-submarine warfare. All of the component parts necessary for the assembly of the hulls were imported, by arrangement with the British Admiralty, from the Fairmile Company, England. Work was started in January, 1942, and the average time of building in England of one boat of this novel type of construction in 40,700 man-hours was bettered by the Auckland firms of Associated Boat Builders Ltd. (4 boats), Shipbuilders Ltd. (3), Chas. Bailey and Son, Ltd. (3), and P. Vos, Ltd. (2) with an average of 35,000 man-hours per boat. These firms were required to build the keels and furnish the Kauri deck planking, in addition to assembling the parts received. The splendid record was a tribute to New Zealand ingenuity and industry, but it also demonstrated what could be accomplished through advanced planning and advanced procurement. One non-propelled steel oil barge of similar design to that used by the Union Steamship Company was built for the N. Z. Navy by the Wellington Patent Ship Company. In addition to the foregoing, approximately twenty-seven small boats were constructed as refueling barges, crash launchers, flare path dinghies, etc. for the R.N.Z.A.F. (Air Force). The shipbuilding program for New Zealand military units is summarized below. Round figures are given of the costs, $3.25 being considered as equal to one New Zealand pound.

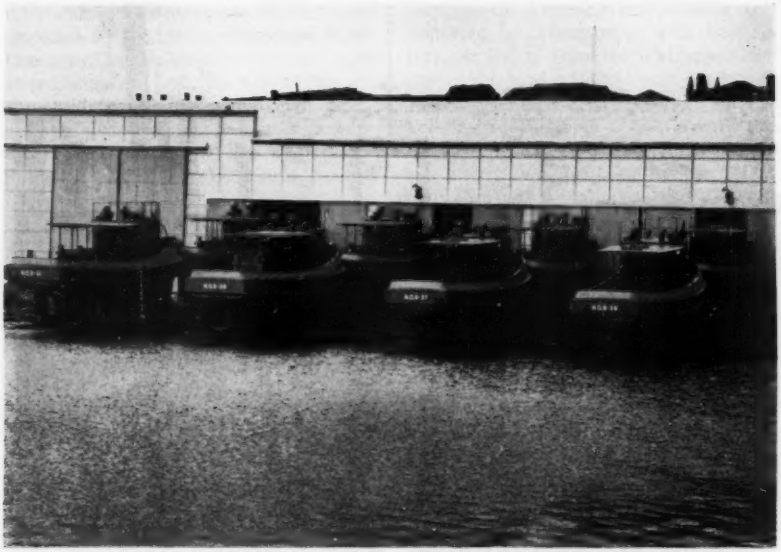
For New Zealand Navy		
Minesweepers, Composite	4 at $195,000	$ 780,000
Minesweepers, Steel, 125′x23′-6″x13′-6″ depth	9 at 195,000	1,755,000
Fairmiles, 112′x17′-10″, 4′-10″ draft	12 at 113,750	1,365,000
Oil Barge, Steel, 180′x36′-0″x 15′3″ depth	1 at 162,500	162,500
For R.N.Z.A.F.		
27 Refueling Barges, Launches, Dinghies, etc.		65,000
Total Costs		$4,127,500

Launching of the USS Y F 1039 on 21 December 1944, in Auckland.

III. UNITED STATES SHIPBUILDING PROGRAM

This program was most intriguing, because of the many facets. United States ships were to be built in a foreign country. Our thinking had to be adjusted to the hands doing the work. Thinking on both sides was based on the fact that we were all on the same team with the same purpose—to do our best to ensure an early victory. The big thrill to me was when the USS YF 1038 was completed, commissioned and delivered. This was the first U. S. Naval Vessel built in New Zealand. Miss Betty L. Cramp of Auckland was the sponsor, as proxy for the author's wife and was present, along with the Lord Mayor of Auckland, and other officials, at the commissioning ceremony. Later, Miss Cramp was sponsor "on her own" for the last U. S. Naval vessel launched in New Zealand, the USS YF 1045.

This program had its beginning in August, September and October, 1942, when representatives of the Southwest Pacific Command, officers of the Army of the United States, came to New Zealand and made at first, tentative, and later, a definite oral commitment, that boats were needed by the Southwest Pacific Command; that the type of boat would be determined at a later date after conferences; and that definite orders would be forthcoming. Almost concurrently therewith, representatives of the South Pacific Command, seeing the possibilities of a ship construction program in New Zealand, entered the picture with the same view. Various types of boats were discussed, including barges, and, as might be expected, the types of boats decided upon for construction were predicated upon facilities



Eight (8) 45′ motor towboats under construction for U. S. Navy outside of fabricating shop of United Shipbuilders, Auckland, New Zealand.

available for shipbuilding, the possible expansion of such facilities, the materials available, and those which would likely be forthcoming, taking available personnel, particularly in the engineering field, into consideration. The New Zealand Government gave a definite "no" at first, because of the difficulties encountered during their own shipbuilding program. The United States authorities assured them of a competent officer to direct the program and of delivery of the materials and equipment from the United States, which New Zealand lacked. New Zealand was invited to construct buildings, building ways, assembly plants, and make arrangements as to the establishment of the necessary shipyards. This eventuated in:

(a) The establishment of Steel Ships, Ltd., French Street, Mechanics Bay, Auckland. This plant fabricated the steel tugs by welding together large sections, built by others and transported to the site in large trailers. A training school was established for welders on the projects at this and associated firms. The tugs were built in cradles on wheels, which were rolled out on tracks on specially constructed piers when the hull work was completed, where they were picked up by the 75-ton harbor crane *Matua* and made waterborne. Twenty minutes later, the crane would lower the heavy duty Atlas engine into the tug and then lower the engine casing and top into place. This plant, having served its purpose, was closed about November 1, 1945.

(b) The construction of an enclosed shipbuilding plant on the site occupied by the Kauri Timber Company before the Great Fire to house three 114-ft. small-cargo vessels, denoted powered

lighters, and eight 45′ tugs on shipways, with the necessary facilities to accomplish the work. This plant, on Fanshawe Street near Victoria Park, was an amalgamation of five old companies, and was known as United Ship and Boat Builders, Limited. The facilities of this plant and the yard above (in (a)) were designed entirely for *building,* and consequently were not used extensively for *repair* of vessels. This plant served its purpose and was closed on April 4, 1946. The Auckland Harbor Board immediately took steps to utilize the building and the adjacent portion of the harbor for a peacetime project, which had been contemplated for many years. The machinery work on the 114-ft. vessels was accomplished by Mason Brothers, Ltd. and Steel Ships, Ltd. That on the 45-ft. tugs was performed generally by a very small firm, Allerly Brothers.

(c) The expansion of Seagar Brothers, Ltd. on Beaumont Street, Auckland. This company has two shipbuilding ways and old repair facilities. The adjacent firms of Shipbuilders, Ltd. and Chas. Bailey and Son, Ltd. performed the shipwright work on the 114-ft. powered lighters built at this plant and Seagar Brothers the boiler work (structural work would be our equivalent term) and the installation of machinery. It is one of the oldest, and the most comprehensive ship repair plant in Auckland, and is still operating.

(d) The adaptation of the plant of Stevenson and Cook, Ltd., Port Chalmers, Dunedin. This old plant had two covered ways, but its facilities were used extensively by us for certain long-term overhauls to reduce the pace of steel and other construction to that caused by the scarcity of shipwrights in the South Island. This condition was slightly improved by the employment of carpenters from Christchurch and vicinity. This plant is now in operation on a reduced scale and is engaged in making routine repairs to ships calling at Dunedin.

(e) The cost of these additional facilities is estimated at 297,000 N. Z. pounds. The residual value in early 1946 was estimated to be only 67,000 N. Z. pounds, due to the complete cessation of all shipbuilding.

(f) The subcontracting through 212 different firms, principally in Auckland, as the planning progressed.

(g) The furnishing of an office to us, gratis, by the New Zealand Government, in the Smith Building, Albert Street, Auckland. This was the headquarters of the American shipbuilding program until Christmas 1945. I then moved this and all of the Navy and Army activities into our Port Quartermaster Building and Warehouse on Quay Street, opposite Princess Wharf.

The contracts for the program were in the form of two small sheets of paper, one bearing A.S.O. (U.S. Armed Services Order) No. 2657 dated 22 November 1942, and the other, A.S.O. No. 4217, dated 19 March 1943. The Commander South Pacific in his letter of 8 June 1943 to the Commander-in-Chief, Southwest Pacific Area, officially confirmed these orders and sent copies of the letter to various authorities, including ComServRonSoPac, ComServPac, CinCPac and the Chief of Naval Operations. General MacArthur replied to ComSoPac in letter of 15 June 1943. A.S.O. No. 2657 is the contract for six (6) 114-ft. Powered Lighters or small-cargo vessels, fifteen (15) 75-ft. Steel Oceangoing Tugs and twenty-five (25) 45-ft. Wood Motor Tow-Boats for the Southwest Pacific Command. All of these were completed and delivered to

the Southwest Pacific Command. A.S.O. No. 4217 is the contract for sixteen (16) 114-ft. Powered Lighters, fifteen (15) 75-ft. Steel Tugs and twenty-five (25) 45-ft. Wood Motor Tow-Boats for the South Pacific Command. Nine (9) 114-ft. Lighters, five (5) 75-ft. Tugs and all twenty-five (25) 45-ft. Tow Boats were delivered prior to VJ Day to the South Pacific Command for service in forward areas. The action taken with respect to the remaining completed boats and those unfinished on VJ Day is contained in subsequent paragraphs. It should be noted that the Southwest Pacific Program was known as the Army Program and the South Pacific Program as the Navy Program. However, the nature of the placement of these orders and their consummation in an area under U.S. Navy command made them U.S. Navy responsibility. With respect to the A.S.O.'s, the orders were to be completed in the order of placement, the Southwest Pacific Command getting their vessels first. Mention should be made of the truly splendid service rendered by General MacArthur's personal representative in New Zealand, Major, later Lieutenant Colonel, John H. Dinkins.

The Southwest Pacific Command considered and actually had A.S.O. No. 2120 approved for the construction of ten additional 114-ft. Powered Lighters with the understanding that the deliveries would alternate with those of the South Pacific Command. The order was later cancelled by them. The Southwest Pacific Command also introduced a proposal to build steel vessels 120 feet long. The advanced planning of this project revealed too many material problems and manpower adjustments to make the project feasible at the time.

Mention should be made at this time of urgent construction for U. S. Armed Forces stationed in Fiji, during the period of planning and fabrication for the U. S. Shipbuilding Program. One hundred and forty wooden barges, 50 feet long, were constructed on an imperative order by Messrs. Love Construction Company in Dunedin and a syndicate of coach-building firms in Christchurch. One hundred amphibian steel trailers on another imperative order were constructed by the coachbuilding firms in Auckland and Christchurch. These barges and trailers were non-propelled. Many of the artisans from the coachbuilding firms were then drawn into shipbuilding. During the last year of the war sixty wooden wherries or dinghies, as denoted by the New Zealanders, were built for the PCs of the Pacific Fleet. The wherries were equipped with outboard motors from our stock and from other bases in New Caledonia and the Solomons. Another order, which was chargeable to a different account, was that of small craft for recreational purposes at advanced bases, in the South and Central Pacific.

The management of the program, the advanced planning, the planning, design, procurement, general supervision of construction, conduct of trials, acceptance, commissioning or placing in service and arrangements for personnel to man the boats emanated from our New Construction Office in the Smith Building. Associated with us were two New Zealand agencies, to an amazing degree independent of each other, the Controller of Shipbuilding and the two new functional groups of the Marine Department. The Controller of Shipbuilding allocated the basic contracts and the numerous subcontracts. One of the new Marine Department groups provided inspection and drafting services, and the other was

an accounting group for inspecting contractors' books relative to wages and hours of work which were fixed in all employment by law; contractors' procurement and other costs. Our New Construction Office and our Hobson Wharf Sub-office handled the procurement, warehousing in our own buildings and the actual issuance of all materials and equipment of U. S. origin, directly to the contractors and sub-contractors and, later, upon arrival of the prospective commanding officer and the crew of each vessel, directly to the vessel.

The advanced procurement paid dividends through timely arrival of materials and equipment. The only serious delay occasioned by late delivery was in engining the 45-ft. Motor Tow Boats on account of the late receipt of the DNX engines, which were delayed at home by a critical shortage of anti-friction bearings for the 3 to 1 reduction gears. The program was delayed and rightly so, at times by the precedence of ship repairs, which had Priority No. 1 in the New Zealand area. It is sufficient to state that 212 firms were engaged almost entirely in the U. S. Shipbuilding program over a period of three years and an additional 97 firms with all of their facilities for an equal period in U. S. ship repairs.

The boats were built by New Zealand workmen with, generally, New Zealand materials and U. S. machinery and equipment. There were some exceptions, e.g., English Ruston Hornsby diesels were used for the winches and U. S. or rewound N. Z. motors were used with N. Z. manufactured fans for oil burners on galley ranges. The anchor handling arrangement and some of the switchboards were manufactured in New Zealand. On the other hand, 67% of the steel and planking for the steel tugs and the powered lighters were furnished through the regular channels of Lend Lease, as Australian steel was no longer available and the New Zealand stockpile of steel was about exhausted; and the unprecedented utilization of heart Kauri for the fifty-two boats had practically exhausted all that was available. We furnished equipment to assist in cutting and hauling this large timber to the mills, but the use exceeded the supply. Oregon pine was substituted for Kauri for planking. The installation of New Zealand totara wood, one inch thick, as sheathing over the underwater planking, proved to be highly satisfactory, according to the latest docking reports.

The fifty 45-ft. Wood Motor Towboat hulls were constructed at the rate of eight every five to six weeks. All, except one, were constructed at the plant of United Ship and Boat Builders. Immediately upon completion of the machinery and electrical work and outfitting, they were sent to forward areas as deck cargo. (An EC-2 ship could take seven as a deck load.) The 75-ft. Tugs and the 114-ft. Powered Lighters proceeded by two's, as a rule, under their own power. Nearly all of them, unfortunately, in their long trips passed through storms and winds of gale or greater intensity. They demonstrated their seaworthiness in a remarkable and practical manner, although with considerable discomfiture to personnel. Lieut. (j.g.) "Tommy" Thompson and Ensign Murfin, each in a 75-ft. Steel Tug rode out the worst storm of the war years in the South Pacific, reporting consistent readings of 64° each way on the clinometer for a period of about 48 hours, the vessels arriving in Noumea sans paint topside and only a few bent railings. The progress of building each boat accepted and placed in service is indicated in the following tables. It should be noted, that in spite of the increasing tempo of ship repair work, each contractor was generally consistent with each succeeding vessel in reducing the number of days to build:

45-ft. Wood Motor Towboats

		Name	*Delivery Date*
WT1		*Kupe*	28 August 1943
WT2		*Koroki*	28 August 1943
WT3		*Kawa*	28 August 1943
WT4		*Kanu*	28 August 1943
WT5		*Kaihau*	28 August 1943
WT6		*Korokai*	28 August 1943
WT7		*Kiwa*	2 October 1943
WT8		*Kanapu*	2 October 1943
WT9			27 November 1943
WT10			27 November 1943
WT11			27 November 1943
WT12			27 November 1943
WT13			27 November 1943
WT14			27 November 1943
WT15			27 November 1943
WT16			27 November 1943
WT17			11 December 1943
WT18			11 December 1943
WT19			11 December 1943
WT20			11 December 1943
WT21			18 December 1943
WT22			18 December 1943
WT23			18 December 1943
WT24			18 December 1943
WT25		*Kaiwaka*	18 December 1943
NOB26	BuShips Registry No. C-68739	*Later YTS2*	25 March 1945
NOB27	BuShips Registry No. C-68740		25 March 1945
NOB28	BuShips Registry No. C-68741	*Later YTS1*	28 March 1945
NOB29	BuShips Registry No. C-68742		4 April 1945
NOB30	BuShips Registry No. C-68743		4 April 1945
NOB31	BuShips Registry No. C-68744		17 May 1945
NOB32	BuShips Registry No. C-68745		25 March 1945
NOB33	BuShips Registry No. C-68746		17 May 1945
NOB34	BuShips Registry No. C-68747		17 May 1945
NOB35	BuShips Registry No. C-68973		17 May 1945
NOB36	BuShips Registry No. C-68974		4 April 1945
NOB37	BuShips Registry No. C-68975		4 April 1945
NOB38	BuShips Registry No. C-68976		4 April 1945
NOB39	BuShips Registry No. C-68977		17 May 1945
NOB40	BuShips Registry No. C-68978	*Later YTS4*	28 March 1945
NOB41	BuShips Registry No. C-68979		17 May 1945
NOB42	BuShips Registry No. C-68980		17 May 1945
NOB43	BuShips Registry No. C-68981		22 January 1945
NOB44	BuShips Registry No. C-68982		22 January 1945
NOB45	BuShips Registry No. C-68983	*Later YTS3*	22 January 1945
NOB46	BuShips Registry No. C-68984		22 January 1945

45-ft. Wood Motor Towboats

		Name	*Delivery Date*
NOB47	BuShips Registry No. C-68985	*Later YTS5*	22 January 1945
NOB48	BuShips Registry No. C-68986		16 February 1945
NOB49	BuShips Registry No. C-68987		16 February 1945
NOB50	BuShips Registry No. C-68988		25 March 1945

114' Powered Lighters

Ship	*Name*	*Keel Laid*	*Delivery Date*	*No. of Days*	*Cont'r*
OL-1A	*Dallington*	5-12-43	10- 6-44	509	Seagar
OL-2A	*Dunedin*	6-16-43	8-23-44	432	US & BB
OL-3A	*Duntroon*	6-24-43	9-22-44	453	US & BB
OL-4A	*Dunback*	9- 2-43	9-10-44	373	US & BB
OL-5A	*Dannevirke*	7-28-43	8-30-44	397	Seagar
OL-6A	*Devonport*	10-23-44	10-20-44	357	Seagar
YF1038		2- 2-44	12-21-44	319	Seagar
YF1039		4-27-44	4-29-45	367	Seagar
YF1040		10- 9-44	8-12-45	303	Seagar
YF1041		7-19-44	3-29-45	250	US & BB
YF1042		7-18-44	3- 3-45	225	US & BB
YF1043		7-24-44	5-11-45	287	US & BB
YF1044		12-11-44	7-12-45	211	US & BB
YF1045		2- 5-45	8-24-45	199	US & BB
YF1050		6- 5-44	5-31-45	356	(Stevenson & Cook, Dunedin)

NOTE: US & BB = United Ship and Boat Builders Limited.

75' Steel Tugs

Ship	*Name*	*Keel Laid*	*Delivery Date*	*No. of Days*	*Cont'r*
ST1	*Coatesville*	5-19-43	5-27-44	373	Steel Ships, Ltd.
ST2	*Cambridge*	6-15-43	5-27-44	342	Steel Ships, Ltd.
ST3	*Canterbury*	3-13-43	7- 5-44	390	Steel Ships, Ltd.
ST4	*Cargill*	4- 5-43	7- 5-44	368	Steel Ships, Ltd.
ST5	*Carterton*	7-14-43	8-12-44	393	Steel Ships, Ltd.
ST6	*Castlecliffe*	7-24-43	8-12-44	383	Steel Ships, Ltd.
ST7	*Catlins*	9-29-43	9-18-44	349	Steel Ships, Ltd.
ST8	*Caversham*	10- 7-43	9-18-44	341	Steel Ships, Ltd.
ST9	*Chatham*	2-17-44	10-17-44	240	Steel Ships, Ltd.
ST10	*Christchurch*	5-30-44	10-17-44	137	Steel Ships, Ltd.
ST11	*Clinton*	6-27-44	11-16-44	139	Steel Ships, Ltd.

75′ Steel Tugs

Ship	*Name*	*Keel Laid*	*Delivery Date*	*No. of Days*	*Cont'r*
ST12	*Clive*	7-19-44	11-16-44	117	Steel Ships, Ltd.
ST13	*Collingwood*	8- 9-44	12- 7-44	118	Steel Ships, Ltd.
ST14	*Cook*	8-28-44	12- 7-44	101	Steel Ships, Ltd.
ST15	*Culverson*	9-20-44	1-16-45	116	Steel Ships, Ltd.
YTL617		10-25-44	5-25-45	210	Steel Ships, Ltd.
YTL618		11-18-44	5-21-45	183	Steel Ships, Ltd.
YTL619		2- 3-45	6-16-45	133	Steel Ships, Ltd.
YTL620		2-26-45	7- 3-45	127	Steel Ships, Ltd.
YTL621		3-23-45	7-27-45	124	Steel Ships, Ltd.
YTL622		4-18-45	8- 8-45	110	Steel Ships, Ltd.
YTL623		5-16-45	9- 1-45	105	Steel Ships, Ltd.

The Reverse Lend Lease costs for this program totaled 2,413,268 pounds, 18 shillings and 8 pence. The author signed the official N. Z. invoice early in February, 1946. This can be translated roughly into $7,800,000. The breakdown is as follows, with approximate costs of United States furnished materials and equipment indicated in separate columns:

		N. Z. COSTS		*U. S. COSTS*		*TOTAL*	
Qty.	*Type*	*Each*	*Total*	*Each*	*Total*	*Each*	*Total*
50	Wooden Motor Tow Boats 45′x14′x7′ Depth	$24,000	$1,200,000	$11,000	$550,000	$35,000	$1,750,000
22	Oceangoing Steel Tugs, 75′-9″x18′x10′ Depth	90,000	1,980,000	45,000	990,000	135,000	2,970,000
15	Powered Lighters, Small Cargo Vessels, 260-ton Capacity, Composite type construction, 114′-6″x24′x11′ Depth	250,000	3,750,000	40,000	600,000	290,000	4,350,000
40	Barges, wood, prefabricated 50′	4,150	166,000	—	—	4,150	166,000
100	Barges, wood, completed, 50′.....	4,750	475,000	—	—	4,750	475,000
100	Amphibian Trailers, steel	2,125	212,500	—	—	2,125	212,500
36	Wherries, wood, 12′	275	9,900	—	—	275	9,900
24	Wherries, wood, 14′	275	6,600	—	—	275	6,600
	Total		$7,800,000		$2,140,000		$9,940,000

No vessels were accepted after VJ Day. Two vessels, the YTL-622 and the YTL-623, were turned over to the New Zealand Government subsequently. The Marine Department stated that the 622 "is utilized as our ferryboat in Auckland for miscellaneous jobs—towing vessels to Greenhithe, etc. and is admired by those who come in contact with her." The status of the vessels on order and not accepted is shown in the tabulation on the next page:

114' Powered Lighters

Ship	*Builder*	*Keel Laid*	*Estimated Completion Date*	*Percentage*	*Completed*	*Disposition*
YF-1046	US&BB	2-15-45	10-15-45	95%		Completed by N. Z. Govt. (a)
YF-1047	US&BB	6-20-45	10-30-45	80%		Completed by N. Z. Govt. (b)
YF-1048	Seagar	12-21-44	10-30-45	85%		Completed by N. Z. Govt. (c)
YF-1049	Seagar	7-23-45	11-30-45	65%		Left as is on building ways.
YF-1051	Dunedin	5- 7-44	10-25-45	92%		Completed by N. Z. Govt.
YF-1052	Dunedin	2- 2-45	11-30-45	60%		Left as is on building ways.
YF-1053	US&BB	7-30-45	11-30-45	35%		Dismantled and materials salvaged.

Notes:

(a) Now M. V. *Aranui.* Charterd by Northern Steamship Co., Ltd.

(b) Now M. V. *Melva.*

(c) Now M. V. *Rosalie.* Chartered by Northern Steamship Co., Ltd.

YTL-624	Steel Ships	6- 5-45	9-30-45	96%	Completed by N. Z. Govt. and sold to UNRRA.	
YTL-625	Steel Ships	6-20-45	10-15-45	92%		
YTL-626	Steel Ships	7-12-45	10-20-45	85%		
YTL-627	Steel Ships	7-30-45	11- 8-45	45%		Left as is on building ways.
YTL-628	Steel Ships	8-25-45	11-18-45	25%		Left as is on building ways.
YTL-629	Steel Ships	9-17-45	11-20-45	14%		Left as is on building ways.
YTL-630	Prefabricated Sections			12%		Salvaged or junked.
YTL-631	Ready for erection in Cradles			7%		Salvaged or junked.

The value of U. S. materials built into the vessels not accepted by the United States was as follows:

YF-1046	$ 32,804.25
YF-1047	10,912.50
YF-1048	25,905.32
YF-1051	32,909.10
YTL-624	41,223.22
YTL-625	40,623.32
YTL-626	39,872.98
Total	$224,250.69

These materials and equipment, however, were not sufficient for New Zealand to complete the vessels on their hands after VJ Day. The New Zealand authorities procured small quantities of materials from their own stocks and on the local markets, but they obtained most of the items from our stock. The necessary materials and equipment were obtained first by direct purchase from us and later through the remainder of our shipbuilding stock being sold by the U. S. Foreign Liquidation Commission in their first over-all sale to the New Zealand Government. The finalizing of the shipbuilding program started with my telegram of VJ Day to the Honorable Secretary to the Treasury of New Zealand and his reply to me, in which it was mutually understood that the United States Shipbuilding contracts were considered canceled.

IV. U. S. SHIP ALTERATIONS AND REPAIR PROGRAM

The total number of U. S. ships receiving repairs and alterations during the war period in New Zealand totaled 1089. Auckland took care of 763, Wellington 239, Dunedin 45, Napier 27 and Lyttleton 15. As opposed to the 212 firms engaged in the new ship construction program; 309 firms were assigned to ship repairs. Financial statistics are not given herein for ship repairs, due to complications arising from U. S. Navy, Army and War Shipping Administration cost accounting methods employed on U. S. furnished materials, and the New Zealand separation of costs incurred for services, procurement and special projects.

Closely allied to the foregoing, was the program for restoration of vessels and craft impressed by the South and Southwest Pacific Commands during the early and pressing months of the war. The vessels included several coastal vessels, the only crane ship in New Zealand and numerous smaller craft of many descriptions. After these craft had served their purposes or had been supplanted by appropriate military types from the United States, they were returned to New Zealand for reconversion and restoration to their respective pre-war status. The advanced age of some of these craft when taken over, the imperative hard usage at the most advanced outposts, and the changes made, as a rule, at advanced bases to make them suitable for military purposes, frequently resulted in extensive projects; in effect, rebuilding about 25% of the impressed craft.

The advent of United States ship repair work in New Zealand began on 16 May, 1942, when the U.S. Navy Repair Ship, USS *Rigel*, started operations as a ship repair unit at Hobson Wharf, Auckland for United States vessels. Ship repairs were "farmed out," gradually at first; then more as the practicability of utilizing shore-based facilities became apparent. With the prospect of imminent detachment of the *Rigel* for work in a forward area, a Material Office was established in the Government Building, Auckland under Lt. Comdr. S. M. Cox, who also retained, for a while, his post as Commanding Officer of the Receiving Barracks.

On 2 August, 1942, an office was set up in the Government Building, Stout and Ballance Streets, Wellington for Lt. Comdr. R. K. Hodsdon, as the U.S. Navy Material officer for Wellington. This office functioned smoothly from the start because practically all work was channeled through Cable and Co. and the Wellington Floating Dry Dock, who had been engaged in ship repair for many years prior to our arrival. After Comdr. Hodsdon's detachment, Admiral Boedell of the British Navy assigned Commander Earnshaw to me as my representative in Wellington.

The organization of ship repair and ship construction in New Zealand was formalized by Comsopac and Comseronsopac organization chart approved 23 August 1943. The author was assigned in charge of "New Zealand Dry Docks and Repair Yards" with Lt. Comdr. Cox in Auckland and Lt. Comdr. Hodsdon in Wellington. (Later, Lt. Comdr. Jack Enoch Clark and Lieut. Thomas William Carey were successively assigned as Officers in Charge, U.S. Naval Activities, *Dunedin* with principal duties in ship repair and new construction.) At the time of his assignment, the author was operating as Repcomseron with nearly all of his time engaged in salvage work, principally in getting torpedoed and damaged ships (and their cargo) to their destinations. It will be remembered that this work was started by our present Chief of the Bureau of Ships, Rear Admiral Homer N. Wallin.

The purpose of the organization "New Zealand Dry Docks and Repair Yards" was to:

(a) Act as Supervisor of Shipbuilding for the United States Armed Forces—New Ship Construction Program. This work has been described in the previous portion of this article.

(b) The Ship Maintenance, Ship Repair and Ship Alteration work on United States Navy, United States Army, and War Shipping Administration Vessels in the area. This work included:

1. Advanced planning.
2. Planning.
3. Initiating advance procurement.
4. Supervision of work.
5. Acceptance of work for the United States.
6. Certification of vouchers for payment.
7. Auditing.

(c) Operate the U. S. Ammunition Depot at Kauri Point, Auckland Harbor. The Ammunition Depot was closed on 1 Sept. 1944. Thereafter ordnance repairs were made by mechanics from HMNZ Dock Yard and through private contractors. The necessity for stocking ammunition in the area no longer existed as much of this work was handled at Espiritu Santo.

(d) Operate the various Degaussing Activities. With the detachment of U. S. Military personnel this work was handled entirely by reserve officers of the British Navy who reported to me.

(e) Act as the Safety Officer.

(f) Warehouse salvagable materials for reissue.

(g) Act as Excess Material Officer.

(h) By representation of this office on HMNZ Central Docking Committee for questions relating to dry docking and policy work if it interfered with the British or local Military and Merchant Ships.

(i) Decommission vessels turned back to the New Zealand Government and commission new vessels built in the area.

(j) Handle miscellaneous Navy work not specifically assigned to Supervisor of Shipbuilding and Industrial Manager.

(k) Act as Port Director and coordinate with the senior officer present afloat Military matters such as Courts-Martial and Shore Patrol.

The facilities at Lyttleton were used to some extent. An outstanding example of their use was in the repair of a U.S.A.T. vessel, the *Barbara C*, in August, September and October 1944. This was done because of the availability of the dry dock for extensive underwater repairs. No other dry dock could be made available for such a long period. On this particular occasion the new Ship Construction Program in Auckland was hampered by the sending of about 40% of the shipwrights to Lyttleton to work on the *Barbara C*.

The HMNZ Dockyard, Devonport, Auckland was utilized when repair and maintenance work on British vessels did not occupy the services of the small force and the limited facilities of that yard. The Calliope graving dock in that yard is large enough to take any of our cruisers but it should be mentioned that the control of the dock was vested in the Central Docking Committee of the New Zealand Government rather than with the British Navy.

The volume of repairs to United States vessels as handled in the respective localities aforementioned were as follows:

1942:

Auckland—Private firms and USS *Rigel*	50%
Auckland—HMNZ Dockyard	5%
Wellington	45%

1943:

Auckland—Private firms	60%
Auckland—HMNZ Dockyard	10%
Wellington	27%
Dunedin	3%

1944:

Auckland—Private firms	60%
Auckland—HMNZ Dockyard	12%
Wellington	15%
Dunedin	8%
Lyttleton	5%

1945:

Auckland—Private firms	88%
Auckland—HMNZ Dockyard	0%
Wellington	9%
Napier (handled from Auckland)	3%
Dunedin	0%

The reasons for Auckland accomplishing the great majority of the repairs were as follows:

(a) The AFs coming to New Zealand called at Auckland for loading, occasionally at Napier. These ships made a round trip in from two to four weeks and due to their age and the fact that they had been improvised to carry meats, required constant maintenance, repair and replacement.

(b) Auckland was the closest port in New Zealand to bases of the South and Southwest Pacific Commands.

(c) More work could be accomplished in Auckland than in any other port because of the greater number of factories, machine shops and industrial establishments located in the Auckland Harbor area. The new ship construction program in Auckland necessitated new shipbuilding establishments, enlargement of the old ones and when occasion demanded, taking artisans from new construction and assigning them as needed for ship repairs. Thus, in Auckland, as in other places throughout the world, new ship construction provided the leaven for the ever varying volume of ship repairs.

The firms engaged in ship repair included all of the manufacturing and construction firms, and firms providing services including the department stores, of Auckland, and most of the other cities in New Zealand. To assist in the co-ordination of this work, the New Zealand Government placed three agencies of the Government at our disposal, the British Navy, actually acting through the Naval Engineer Overseers, Auckland, Wellington and Dunedin, the Controller of Shipbuilding and the many agencies of the Marine Department.

New Zealand contributed to an outstanding degree by furnishing skilled workmen and making available all of the possible facilities for utilization in ship repair work (which had the highest priority) and for new ship construction (which held a priority at various times of second, third and fourth). New Zealand also contributed by furnishing materials to the limit of her capacity. The skill of the average New Zealand mechanic is of the very highest order. This is due to the absence in New Zealand of a highly industrialized machine system where the average industrial worker is but partially trained in a particular trade but highly specialized in his particular job. Much of the success and expedition of repairs can be attributed to the average mechanic being capable of performing all of the duties in his particular trade in an excellent manner.

V. BRITISH PROGRAMS

Upon completion of the fifty 45-ft. Motor Tow Boats, the British Ministry of War Transport placed an order for twenty-four identical tugs, except for the propulsion machinery of slightly less horsepower. Twelve of these tugs were canceled after VJ Day and the other twelve were completed for British Eastern Supply Group countries. Actually, eight were sold to UNRRA.

Shortly after the foregoing program was initiated, the High Commissioner for the Western Pacific placed an order for five special purpose vessels, 60 ft. long, for servicing the Pacific Islands. These craft were completed, as were the former, by United Ship and Boat Builders, Limited in Auckland.

The Marine Department represented the New Zealand Government in the acquisition of craft for the New Zealand Navy and also embarked on a program of its own to acquire vessels and small craft for essential war purposes. 138 vessels, most of them in the category of small craft of total value amounting to 1,573,570 pounds, were purchased and 53 vessels with a total replacement value of 3,621,930 pounds, were chartered by the Marine Department. A total of 18 of the 191 vessels passed out of the hands of the New Zealanders to the U. S. Army and U. S. Navy for war service. The 18 vessels so chartered, along with additional craft impressed by the American Armed Forces in the early days of the war, were later returned to the New Zealand authorities.

New Zealand lost five merchant ships as the result of enemy action, but fortunately the loss of life was small—namely nine men. The vessels lost were: *Holmwood, Komata, Hauraki, Awatea* and *Limerick.*

The interesting old ship of the New Zealand-Australia run, the *Maunganui,* used as a troopship during World War I, was converted to a hospital ship in early 1941. The *Maunganui* served throughout World War II, carried 10,000 patients on 17 voyages and steamed 400,000 miles.

Perhaps the most interesting epic of the sea and one kept top secret was that of the recovery of gold bullion from the Royal Mail steamer *Niagara.* On June 19, 1940, the *Niagara* struck a German mine off the entrance to Whangarei Harbor and sank. The *Niagara* carried $8,111,025 of gold bullion. The recovery of $7,790,250 of the gold bullion can be considered a real feat, considering the facts that the salvage operations were carried out in an area infested with mines and that the vessel had settled deeply in the mud and acquired a heavy list after sinking in 436 feet of water.

VI. CONCLUSION

As of midyear 1947, shipbuilding was non-existent in New Zealand, except for Mason Brothers and Seagar Brothers building a few 55′ steel fishing vessels for UNRRA. The available facilities were 25% of that in World War II.

As of midyear 1947, the facilities and personnel engaged in the field of ship repairs were less than 4% of the peak reached in World War II. The stock of shipbuilding material and ship spares sold by the U. S. Foreign Liquidation Commission proved to be of some value. An outstanding example of this was my long distance handling of repairs, utilizing New Zealand spare parts, for the damaged USS *Merrick,* attached to Rear Admiral Byrd's visit to Antarctica.

Reports on the building of hospitals, camps and warehouses amounting to approximately $26,000,000, the rental of facilities, and the turning over of these U. S. Navy, Marine Corps and Army properties to the New Zealand Government and to others showing the compensation therefor were sent to appropriate agencies of the War and Navy Departments. Similarly the disposition of materials and equipment through the channels of the Foreign Liquidation Commission is the subject of another group of reports to the War, Navy and State Departments. This plus sidelights on incidents occurring during my long tour of duty in that delightful country, might form the basis of another, and, perhaps more interesting story.

IMPLICATIONS AND LIMITATIONS OF THE COMPTROLLERSHIP CONCEPT IN THE OPERATION OF NAVAL SHIPYARDS

COMMANDER J. M. COURT, USN

THE AUTHOR

graduated from the Naval Academy in 1936 and served two and one-half years at sea as an ensign before resigning to enter the shipbuilding business. After experience in production planning at Federal Shipbuilding and Drydock Company and in outfitting at Ingalls Shipbuilding Corporation he was recalled to active duty as a reserve officer in 1940. As a reserve he completed the Naval Architecture and Marine Engineering Course at the Postgraduate School and was assigned duty in Planning at the Philadelphia Navy Yard. Subsequent assignments included wartime duty on various Pacific Fleet Staffs, a tour in BuShips Design Division, and, during the Korean action, service as Director of Maintenance and Repair, Military Sea Transportation Service, Western Pacific. Most recently, he completed the Naval Comptrollership Course at George Washington University, receiving a degree as Master of Business Administration.

I.

In essence, comptrollership is a technique for the management of management. Naval personnel, unfamiliar with business administration and organization, may have as much difficulty grasping the comptrollership concept as the fabled blind men had grasping a mental picture of an elephant. The ideas of individual comptrollers as to their proper functions differ strikingly from company to company and from one government activity to another. The art of comptrollership is in a state of active development. Personality and environment have unusual influence on the scope of the task. The comptroller in government has features of a fiscal commissar, an Inspector General and an auditor. In other features he resembles a chief planner, a credit manager, and a policy trouble-shooter. In a sense he is all these yet none of them, as the discussion which follows should indicate.

The vital preliminary to any enlight-

ening discussion of comptrollership is adequate definition of the term. So many diverse and unprecise conceptions of the comptrollership function exist that unless the term is carefully defined the layman who assays an evaluation of the point of view expressed by someone already familiar with the subject will find his understanding inextricably bogged down in a morass of meaningless nomenclature. For the purposes of this paper, therefore, the comptrollership concept will be defined in nontechnical phraseology and in its broadest sense as the theory that large organizations can best be managed through use of a senior staff officer whose primary (and preferably sole) responsibilities are: a) to establish periodically in terms of some common denominator (usually money) a correlated series of objectives for concurrent achievement by the various operating departments of the organization, b) to establish a fair and comprehensive technique for measuring the progress of each department towards the established objectives, c) to focus management's timely attention on deviations from the planned progress, and thereby to inspire appropriate corrective action either through modified plans or improved performance.

The development of the comptrollership concept has been one of the most significant features of American industrial management in the last thirty years. The pressure for its adoption in business and the necessity for its consideration in the military services derives from the complexity of management problems in large-scale modern industrial enterprises wherein several hitherto incidental considerations have assumed major proportions. For example:

a) it is now extremely difficult to develop for top executive billets in our various great enterprises, men who have adequate understanding and training in all the highly specialized phases of the undertaking, i.e., law, finance, engineering, production, distribution, procurement and personnel.

b) it is also exceedingly difficult to measure accurately the relative importance and the degree of success of the performance in each of these highly diverse sectors of the over-all operation.

c) to cope with the intensified pressure of labor negotiations, tax burdens, and rapid technical developments, the modern executive must have at his fingertips a continuous, concise and consistent evaluation of the status of his enterprise, and the preparation of such an evaluation demands a broader-gauged approach than mere bookkeeping or accounting.

Recognition of the nature and scope of these administrative problems has been evidenced both in industry and in government by the widespread demand for "bright young men" to become special assistants to high executives. Franklin Roosevelt first dramatized the need, early in his administration, for executive reinforcements by the appointment of seven promising young men as his "special assistants with a passion for anonymity." While the famous anonymous assistants of F.D.R. have not usually been associated in any way with the term "comptroller," they were the forerunners of the potent Executive Office of the President as organized by President Truman and they exemplified certain attributes highly desirable in the function of comptrollership, namely:

a) they were active men of recognized executive promise and tact, unbiased by long association with any established department or function.

b) they were directly responsible to the Chief Executive yet supplementary to established departments and offices.

c) they were important neither for the responsibility they carried, nor the following they had, nor the influence they exercised, but rather for the degree to which their accurate analyses and ad-

vice could lighten the executive's burden.

d) their lack of personal interest or formally constituted authority presumably gave them an impartiality and an objectiveness not readily achieved by any regular department or office heads.

Let it be sufficient to observe therefore that there has appeared on the scene, in our complex economic and political system, a species of staff officer variously identified as special assistant, executive assistant, assistant president, minister without portfolio, roving ambassador and comptroller. Whatever these terms may signify they identify executive reinforcements who have ceased to be unique or uncommon, and they appear to fill a need derived from the unprecedented size of our administrative organizations and the diversity of the control problems peculiar thereto.

The impetus behind the comptrollership concept in the Navy is a basic legal directive, the National Security Act Amendments of 1949, inspired by the report of the Hoover Commission on Reorganization of the National Security Organization. In it the following guide-lines were established:

"(Sec 401) There is hereby established the Comptroller of the Department of Defense. The Comptroller shall establish and supervise the execution of principles, policies and procedures to be followed in connection with organizational and administrative matters relating to:

(a) i—the preparation and execution of the budgets
ii—fiscal, cost, operating and capital property accounting
iii—progress and statistical reporting
iv—internal audit, and,

(b) policies and procedures relating to the expenditure and collection of funds administered by the Department of Defense.

"(Sec 402) The secretary of each military department shall cause budgeting, accounting and statistical reporting, internal audit and administrative structure and managerial procedure relating thereto in (his) department to be organized and conducted in a manner consistent with the operations of the Comptroller of the Department of Defense.

"(Sec 405) In order more effectively to control and account for the cost of programs and work performed in the Department of Defense the Secretary of Defense is authorized to require the establishment of working capital funds for the purpose of providing working capital for such industrial type activities as provide common services within or among the departments and agencies of the Department of Defense. The secretaries of the Military Departments shall allocate responsibility within their respective departments in such manner as to effect the most economical and efficient organization and operation of activities for which working capital funds are authorized by this section."

Implicit in the above abstracts of Public Law 216, of the 81st Congress, is the intent to force implementation of the comptrollership concept in the logistic activities of the Armed Forces. From these seemingly innocuous words stem ample legal leverage to exert, through the Defense Comptroller, a determining influence for years to come on the techniques and organizations for the conduct of the Navy's logistic support. Ultimately the influence of the comptrollership concept may well be as fundamental to our military establishment as was the influence of the Congressional Act of 1842 which established the Bureau System. Whether we like the idea is immaterial. Comptrollers are with us to stay awhile.

II.

The largest integrated industrial operation in naval logistics comprises the Shipyards. From the standpoint of payroll, plant inventory and value of product, the yards in aggregate are possibly the most extensive direct industrial undertaking of our government. Hence the results of the present pilot installation of the comptrollership concept at the Philadelphia Naval Shipyard will have major significance outside as well as within the Navy. If the implementation of the comptrollership concept is to bring about a decided improvement anywhere in the field of military management it seems reasonable to expect it to become evident in the relatively stabilized industrial-type undertaking of ship construction and repair. Among close students of the military logistics management problem, however, two antithetical postulates, regarding the efficacy of comptrollership in military installations, indicate the span of opinion on the experiment being conducted at Philadelphia. These postulates may be expressed thusly:

a) that the present management setup for Naval Shipyards (or any government-operated industrial enterprise ancillary to military operations) is demonstrably deficient in a vital sector and demands extensive reorganization in the interest of Defense effectiveness and national economy.

b) that the application of the comptrollership concept and the commercial point of view, generally, to military logistics undertakings, while useful in peacetime economy, will impede effective military operations unless bypassed when active application of military force becomes necessary.

The statement of these two attitudes, it is reiterated, is intended to show the span of opinion among those who have devoted considerable study to the problem. There has been extensive study of the problem and there is extensive middle ground. The approach of the other military Departments to the implementation of Public Law 216 as regards comptrollership, has been much more of a frontal assault and the middle ground there is narrower. Where the Army and Air Force have attempted to establish the concept by administrative order, grafting the comptroller into the organizational tree, the Naval Service has attempted to plant the idea on a philosophical basis in the hope that its influence will be diffused throughout.

To elaborate on the extensive study that has been given the phase of the problem in which we are primarily interested, let us consider some of the analytical reviews of the management of Naval Shipyards which have taken place in recent years. Within the last three years highly objective studies of Shipyard management techniques have been conducted by three independent groups, each with a different professional background, as follows:

a) The firm of Cresap, McCormack and Paget, Management Engineers, was employed on a BuShips contract to determine "the practicability of developing and operating a program of performance measures and management controls covering all major functions of shipyard organization." The central recommendation of this study was to develop standard cost, for use in performance control, through intensive shop-level planning, with emphasis on developing cost consciousness among production personnel.

b) The accounting firm of Price Waterhouse & Co. was employed on a BuShips contract to make a survey of fiscal and accounting problems involved in the administration of the ship construction and conversion programs of

the Bureau of Ships. Their primary recommendation was for the Bureau to develop its own accounting system and to key its controls on Bureau and yard performance to this fiscal reporting system.

c) A Joint Working Panel of military and civil service experts in public fiscal management was instituted by the Comptroller of the Navy to conduct a study of and to develop an accounting procedure for Naval Shipyard operations under the Naval Industrial Fund. Their proposal has been to relabel the Shipyard Fiscal officer "Comptroller" and to draft him a new local accounting system.

In the meantime for the last seven years the Assistant Chief of the Bureau of Ships for Field Activities has devoted much of the effort of his professional staff to the task of systematizing and standardizing shipyard organizations, procedures and performance, and has moved vigorously towards an effective solution of the shipyard management problem.

The entrance of the Bureau of Ships into shipyard management is described in the following quotation from the Cresap, McCormack and Paget Report:

> "The origin of current efforts to devise effective performance controls for the U.S. Naval Shipyards dates to 1945 when the Navy Inspector General proposed, and the Secretary of the Navy directed, that:
>
> —Each Shipyard be placed under the command of an industrially trained officer.
>
> —The departmental administration of Shipyards be vested in the Bureau of Ships.
>
> —The Bureau of Ships undertake, as part of its responsibilities, the development of a long-range plan for the development of performance indices to reflect how satisfactorily the Shipyards are performing, both in terms of service to the Operating Forces and in terms of operating costs."

During the ensuing four years the first two steps have been carried into effect, and notable progress has been made in realigning and strengthening Shipyard organization and in introducing planning staffs to support the key officials. To the observer acquainted with the wartime top-management structure of the Shipyards, these innovations represent major advances in the acceptance and application of modern management techniques.

The third step in the program visualized in 1945 was recognized to be a long-range effort requiring years of research and experimentation. The fact that much of this effort has not paid immediate dividends is attributable to the fact that the Navy, in parts of this undertaking, is pioneering a field of management in which there are as yet few precedents and landmarks. Efforts to date, even where they have seemed to disprove the utility of certain approaches to performance evaluation, represent a definite contribution to the body of knowledge and experience in this field of management. Furthermore, some part of each attempt at performance control has proved its worth and will remain as a permanent part of the techniques of controlling the service and the operating costs of the Shipyards.

The continuous shifting of management responsibilities for the Shipyards is recounted in this abstract from the Price Waterhouse report:

"From the shipyards' standpoint, reporting responsibilities changed several times during the first half of this century. In 1892, the Assistant Secretary of the Navy was given top management control of Shipyards; from 1911 to 1913 this authority rested with a Director of

Navy Yards in the Secretary's office; from 1915 to 1920 it was in a small section under the Chief of Naval Operations; and between 1921 and 1940 it was again in the Secretary's office under successive divisions.

"The first major step in moving the Bureau of Ships toward management control of shipyards occurred on June 30, 1943, when it was charged with the upkeep and operation of the Industrial Departments at all Navy Yards. This was followed by the postwar vesting of complete management control in the Bureau, as already mentioned. At that point, according to Secretary Forrestal, 'the *administration* of the work of the entire Shipyard, and the responsibility for the results produced by all activities of the Shipyard, shall be the direct responsibility of the Bureau of Ships, acting through the Commanding Officer of the Shipyard, and such responsibility is no longer divided among the several bureaus and offices as heretofore.'"

It might seem reasonable to conclude, from the degree of attention the problem had received from sincere, unbiased and competent analysts and administrators in the last few decades, that Naval Shipyard organization already has reached a relatively high state of development and that Shipyard management should be able to meet its major responsibilities adequately without further radical change of structure.

III.

We have now noted on the one hand, the strength and direction of the impinging force, i.e., the comptrollership concept, and on the other hand, the historical background of the present Shipyard management setup. It will help at this point to digress slightly from the central discussion in order to examine in closer detail the existing structure of the Shipyard Organization to see where stand now the functions which would appear to be ultimately destined for the Comptroller's performance. With this objective the following extracts of Standard Shipyard Regulations should be kept in mind.

"Mission.

The Naval Shipyard is a component activity of a Naval Base. The primary mission of the Naval Shipyard is to render service to the Fleet. This service includes providing logistic support for vessels of the Active and Reserve Fleet and for assigned service craft; performing authorized work in connection with the construction, conversion, overhaul, alteration, repair, drydocking and outfitting of vessels as assigned, and related or special manufacturing work.

Duties of Shipyard Commander.

The Shipyard Commander shall administer and direct all of the work of the Shipyard, assume full responsibility for the quality and quantity of work produced and assure the efficient, timely and economical performance of the work of the Shipyard.

Duties of Industrial Engineering Officer.

The Industrial Engineering Officer shall plan and coordinate programs to improve management and shall conduct studies and prepare recommendations for the Shipyard Commander and for each department and office of the Shipyard, as directed by the Shipyard Commander or as requested by a department or office, to improve and simplify organization, administration, procedures and the economical utilization of manpower, materials and facilities throughout the Shipyard. He shall advise on matters affecting the shipyard budget, develop procedures for related financial

controls and review budget estimates of funds for a balanced shipyard budget. He shall develop, compile and analyze work measurement, budget, employment and other statistical data relating to the performance of the shipyard as a whole and of the component parts thereof and shall keep the Shipyard Commander and Heads of Departments and Offices informed of the results of such analyses. He shall serve as Budget Officer, Mobilization Planning Officer and Space Control Officer.

Duties of the Planning Officer.

The Planning Officer is responsible for the approval, issue, and transfer of work instructions and plans, for the initiation of procurement of necessary material and funds for all work requested of the Shipyard by other activities and performed in the Production Department Shops, and for all preparation of man-day and cost estimates for all work issued by the Planning Department and revision thereof as necessary. He will insure that no job order is issued the estimated cost of which is in excess of funds available. In authorizing work he shall give consideration to the productive capacity stated by the Production Officer to be available.

Duties of the Production Officer.

The Production Officer is responsible

—that all work issued for accomplishment by the Production Department is accomplished within the time allowed and the funds allocated and in accordance with applicable instructions and sound engineering practice.

—for notifying the Planning Officer in advance of the release of work on a ship or project and based upon current and prospective work loads, of the limitations on the quantity of work which can be accomplished on that ship or project. When it is determined that authorized work cannot be undertaken within the time or funds available, the Planning Officer shall be advised immediately."

The Supply Officer is also a highly important department head in the Shipyard. The interesting thing about his Department's activity is the extremely comprehensive control setup established within the Supply Department, considerably more elaborate than for the Yard itself.

The functions of some of the Supply Assistants are worth quoting for the light they throw on the comptrollership concept in the Supply part of the Shipyards:

"Duties of the Planning Superintendent (Supply).

b. Preparing and maintaining structural and functional organization charts, analyzing organization structure and proposed changes thereto, and reviewing key civilian position descriptions for organizational alignment.

c. Analyzing existing operation methods and procedures and internal forms and reports with a view toward improved efficiency and effectiveness and coordinating and administering the reports control and forms control programs within the Supply Department.

d. Coordinating and administering work measurement, management control statistics and work improvement programs within the Supply Department.

e. Estimating budget and civilian personnel ceiling requirements and recommending allocations of personnel and funds within the Supply Department.

g. Assisting in determining over-all requirements for allocation of space, material and equipment for internal use.

Duties of Control Superintendent. (Supply).

The Control Superintendent, as head of the Control division, is responsible for the processing of procurement, receipt, and issue documents; the main-

tenance of stock records; the scheduling of material to meet required delivery dates; serving as a liaison between ships in the vicinity and the Supply Department; initiating action to dispose of material; and for matters pertaining to the Controlled Materials Plan.

Organization of the Control Division consists of:

(a) Issue Control Branch;
(b) Stock Control Branch;
(c) Receipt Control Branch;
(d) Procurement Branch.

Duties of Inventory Superintendent (Supply).

The Inventory Superintendent, as head of the Inventory Division, is responsible for the conduct of all inventories in accordance with schedules and special requests, and the reconciliation of stock records and money differences between the actual physical count and the stock record card balances. Organization of the Inventory Division consists of:

(a) Count Branch;
(b) Audit Branch."

Recently included in the Standard Shipyard Organization is the following explanation of the Comptroller's functions:

"Duties of Shipyard Comptroller.

The Comptroller shall be responsible for:

(a)—Implementing and administering the law, policies, regulations, directives and instructions pertaining to the financial operations of the Shipyard, including budgeting, financial statistical reporting, accounting, disbursing, U. S. Savings Bonds issuances, internal accounting control and the procedures relating to such responsibilities;

(b) Acting as adviser and consultant to the Shipyard Commander on financial policy matters, program planning and related areas of financial administration;

(c) Administering accounting and disbursing operations for other naval activities as designated by proper authority;

(d) Directing preparation of the Shipyard's operating budget;

(e) Administering budgetary control programs and developing methods and techniques for use in furnishing budgetary information, analyzing and evaluating budget estimates and coordinating presentation thereof to the Shipyard Commander, and recommending action concerning budget revisions;

(f) Supervising determination of costs of operations and securing reimbursements for work performed;

(g) Establishing overhead rates subject to approval of the Shipyard Commander;

(h) Devising internal control procedures for the Comptroller Department and supervising administration thereof."

The new accounting system, which the Shipyard Comptroller is directed to put into effect and administer is outlined in the Industrial Fund Handbook as follows:

"The principal features of the NIF accounting system are to provide:

1. For the integrity of the "Project Cash Account" by ensuring reimbursement for all work performed and services rendered, and *controlling* the amount of cash to be invested in inventories and work in process.

2. Financial control of commitments, disbursements, reimbursements, cost distributions and to provide other authority to accept entries into the accounting system.

3. For budgets which will provide management with information required to exercise control in the following areas:

a. cash requirements
b. production costs
c. manufacturing and general and administrative expenses.

4. A system of accounts—to provide:

a. Adequate and ready disclosure of the financial condition and operating results of the Shipyard.

b. Adequate control of financial transactions at the site of operations.

c. Effective means for controlling level and validity of inventories, accounts receivable and work in process.

d. Automatic and internal safeguards against clerical errors and collusion.

e. An accrual basis for accumulating and distributing costs accurately and in simplified manner.

f. Control of cost accounting by means of the general books."

Thus we find that the Shipyard Fiscal Director has been relabeled Comptroller and handed a new accounting system by higher authority, but the full implication of the comptrollership concept appears to fall well beyond these beginnings. Possibly over a period of years, a succession of strong personalities could build the actual function up to the theoretical one defined at the beginning of this paper, but the degree of supervision exercised over the Shipyard by outside authority makes this questionable.

IV.

It is axiomatic that the formal organization of any activity presents only a partial and one-sided aspect of its operating set-up. Undeniably, personalities, traditions, informal arrangements and local political influence will exercise independent pressures of varying intensity and, in effect, modify the planned organization into the real day-to-day operating group. Among the unofficial influences a standard pattern or measure is difficult to identify, whereas in the case of the formal organization, the standard pattern is tangible and clearly defined. We do know, however, that below the Shipyard Commander, the senior officers in rank and prestige, the officers whose scope of responsibility make them the kingpins of the mechanism governing yard performance and reputation, are the Production Officer, the Planning Officer and the Supply Officer. Their civil-service counterparts and assistants are usually also the senior and most influential personalities on their side in the yard. Such, then, being the nature of present Shipyard organization, formal, and actual, what difficulties does it present to the installation of a comptroller of the type visualized in the comptrollership concept?

Three primary clashes of interest between the would-be Comptroller and the present set-up must be resolved. First the planning, the progressing and the followup of yard performance is already being done, and done well, by established organizations. Second, the fiscal controls on the productive work of the Shipyard are fundamentally of a secondary nature to the mission of the yard, whereas in Comptroller practice generally these are a direct measure of the primary mission. Third, whereas the Comptroller's primary tools are the accounting and reporting system, the design and employment of these in the Shipyard is already preempted by remote authorities.

To elaborate these points, one by one,

a) The present Shipyard control set-up is, of necessity, dual in nature, that is: The Supply Department has necessary tie-ins with the Navy Supply System and the larger Defense Department producer logistics plan (viz, Controlled Materials Plan) which inhibit decentralized operation; to conform organizationally with this responsibility, Supply already has a very comprehensive comptrollership vested in its Planning

Officer and Control Division. The industrial side of the Shipyard has another control setup built around the Planning and Production Department relationship. To this control system the present Industrial Engineering and Fiscal Officers bear an advisory but peripheral relationship. falling well short of the influence on operations which a true comptroller exercises by our definition. Hence the entry of the Comptroller constitutes a triplication of controls inside the Shipyard. and a duplication of the sort of management control exercised from Bureau level.

b) The primary mission of the Shipyard is not to maintain a precise fiscal balance or profit, as might be the objective of a commercial yard, but is to serve the Fleet as part of a Naval Base. Measurement of actual or potential usefulness to the Fleet is not reducible to precise units. Battles are not won with balance sheets. In peacetime when the Fleet is merely training, the activities deriving from this mission conceivably can best be planned, correlated, and evaluated by a staff assistant of the Shipyard Commander on the basis of translating general schedules drawn up annually in the Navy Department into a program of local effort which will suit local plant capacity and labor force. In wartime, however, just as the legislative authority of Congress, must, for effective action, be largely delegated to the executive branch, so, in the Shipyards existing solely for Fleet service, accurate long range planning loses its feasibility, operations must be conducted on a short range basis dictated by expediency, and the responsibility for planning, progress reporting and follow-up inevitably must be delegated to those who are directly responsible for accomplishment of the work assigned to the yard and who have at their disposal the materials, manpower, and facilities assigned to the task. In wartime the pressures to accomplish the primary mission of a military unit force the secondary activities and formal preliminaries to be left by the wayside. Day to day judgment on the spot supersedes the careful execution of a precisely drawn timetable. The Comptroller becomes a historian, and the Production Officer becomes the guide as well as executor.

c) The primary tools for the exercise of Comptrollership, the authority to devise and develop the accounting and reporting systems, is not in the hands of the Shipyard, nor is it in the hands of the Bureau responsible for management control of the Shipyards. *The Panel Report* (p. 159) states, "Due to delayed clearances and the reporting thereof of charges against the appropriations and allotments, originating from sources outside of the Shipyard, wide variations of monthly costs occur. Under this system it is extremely difficult to determine accurately total costs concurrently with the completion work or at interim closing dates." *The Price Waterhouse Report* (p. 114) states, "Accounting is universally recognized as a management aid in a large scale organization, yet authority to prescribe the Bureau's accounting system appears to rest exclusively in other hands; we have found no delineation of an area in which the Bureau is free to adapt its methods to as best further management's aims."

In summary, effectual implementation of the basic comptrollership concept in the Shipyards would require,

a) Two deeply entrenched and functionally preeminent control systems to be replaced or subordinated.

b) The amelioration of the basic urgency of wartime operations (which originally introduced military organization and discipline into the Shipyards) in order to let orderly annual planning and data-taking govern. In short, the

producer logistics aspect would have to take precedence over the consumer logistics aspect.

c) The management of the Shipyard to be delegated the authority, now remotely situated, over its intended primary control tools, its accounting and reporting systems.

V.

One of the few men who has administered a purely commercial enterprise closely comparable in scope and nature to the Bureau of Ships and its Shipyards is the President of Bethlehem Steel Company, Mr. Arthur B. Homer. Mr. Homer was formerly Vice-President in charge of the Shipbuilding Division, Bethlehem Steel Company, comprising several important building and repair yards on the Atlantic, Gulf, and Pacific Coasts. On the basis of this experience he contributed the chapter, "Shipyard Organization," in the text, *The Shipbuilding Business,* which furnishes the interesting organization chart reproduced here in Figure 1. (For comparison, organization charts of Naval Shipyards and of the Newport News Shipbuilding and Drydock Company are included as Figures 2, and 3 respectively.)

Mr. Homer states:

"*Organization in Standard Yards.* The organizations of the larger privately owned shipyards in the United States, which have been in business for many years, follow closely the basic executive, staff, and line plan. Typically, the directors, president, and general manager compose the executive part of the organization; the service functions responsible to the executive form the staff; and the operating personnel from the works manager to the individual worker make up the line organization.

"Because the type of product from a shipyard is of a variable and diversified nature and almost always is built only under contract with a purchaser and to meet his special requirements, sales organizations are not usually found in shipyards. This function is retained in executive organization and is customarily handled by the president's office or by a vice-president. The magnitude of the contract, the risks involved, and the effect upon all parts of the organization necessitate the handling of such matters by topside officials of both shipyard and purchaser."

The dissimilarity in organizational emphasis becomes clearly evident in comparing the standard commercial shipyard with the Naval Shipyard. Although their setups are closely parallel in composition, they differ significantly in two major relationships.

First, the president (corresponding to the Shipyard Commander) maintains direct contact only with his fiscal, legal, and executive assistants internally. The balance of his contribution to the undertaking can be focused on contacts upward, to the Board of Directors (corresponding to the Bureau of Ships), and externally to his customers, suppliers, and creditors (corresponding to the Fleet, the Navy Supply System and the Navy Comptroller). The presence of an immediate executive subordinate, the general manager, who coordinates the staff and the plant, is a great boon in that routine operational matters proceed without requiring the attention of the president. Thus freed from a plethora of detail, the president can devote his full talent and energy to planning, policy and analysis. What is this but the comptrollership function itself? The president establishes the performance objectives through his estimates section, establishes performance goals through his general manager, analyzes the results through his accounting group.

In the Naval Shipyard no equivalent billet to that of the general manager

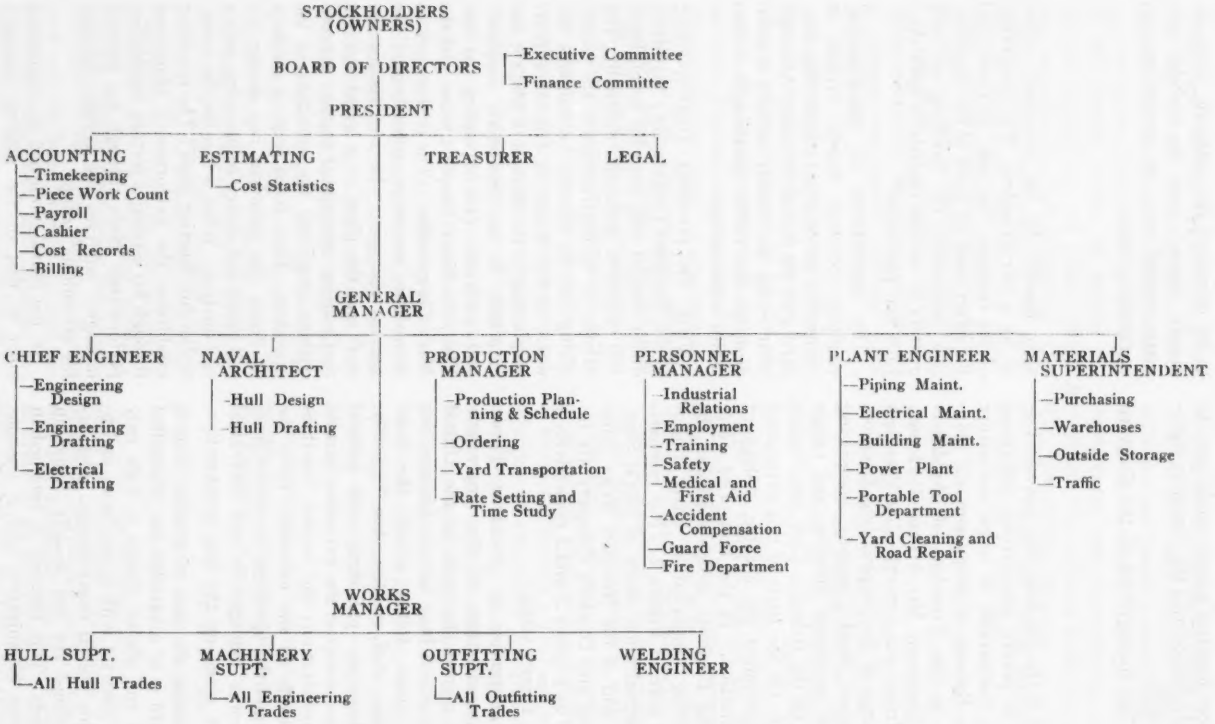


Fig. 1.—Typical Commercial Shipyard Organization.
Taken from "The Shipbuilding Business in the United States of America," Vol. I, pp. 259.

exists, but the Shipyard Commander is in effect a general manager under the Base Commander, militarily, and under the Bureau administratively. His necessary attention to this responsibility places the conduct of Shipyard Comptroller functions on a different level than in a commercial yard. Some such functions are performed at Bureau level while others reside at staff level in the Shipyard. This results in their being undertaken less responsively to the requirements of the Shipyard Commander than had they been situated as in the commercial yard, in executive echelon *between* the general manager and the president and *above* the balance of the staff and line organization.

Secondly, the service relationship of all operating departments to the central purpose of the industry is much more emphatically pointed up in the commercial organization than in the Naval Shipyard. Production Planning is logically a staff function on a level above Production, rather than a parallel, coordinate activity. The materials superintendent similarly is a staff member whose function is to procure, store, and deliver material as best serves production. He has no responsibility as a ship chandler and bears no allegiance to a national mail order house, grocery chain, oil company, or stevedoring firm. He exists solely for the assistance he renders in production. The commercial organization at field or yard level, briefly, is a series hookup, whereas the naval one is in parallel.

VI.

At this point it may be well to review briefly where this discussion stands. We have examined successively the following topics:

a) What comptrollership is in theory and what its impetus in the military establishment is.

b) What the Naval Shipyard organization is in theory and in fact, and what therein is inconsistent with an implementation of the comptrollership concept at yard level.

c) What the commercial shipyard organization is and how it significantly differs from that of the Naval Shipyard, particularly in regard to the situation of the comptroller function.

With this background we are ready to proceed to the heart of the issue, viz., can we apply the commercial solution to the naval problem and get a satisfactory answer?

There are, certainly, features of the commercial yard organization as compared with Naval Shipyard organization which are admirable from the standpoint of efficient shipbuilding and ship repair. The presence of a general manager or immediate executive subordinate, call him what you may, to coordinate the service functions to the requirements of the central purpose of production is particularly attractive. The situation of comptrollership at executive rather than Bureau or staff level is also advantageous. But will these organizational changes really improve the capacity of the Shipyard to accomplish its mission? Does the relationship of the Naval Shipyard to the Fleet bear close resemblance to the relationship of a private shipyard to the customer?

The Fleet looks to the Shipyard for much more than merely new ships or occasional repairs. The home yard maintains comprehensive technical files for assigned ships, necessarily in much greater detail, but otherwise much as the home office of a steamship company does for its ships. All plans, instruction books, alteration data, test data, performance, data, etc., are kept up by the home yard. Hence the Planning Department has a

Taken from "The Shipbuilding Business in the United States of America," Vol. I, pp. 259.

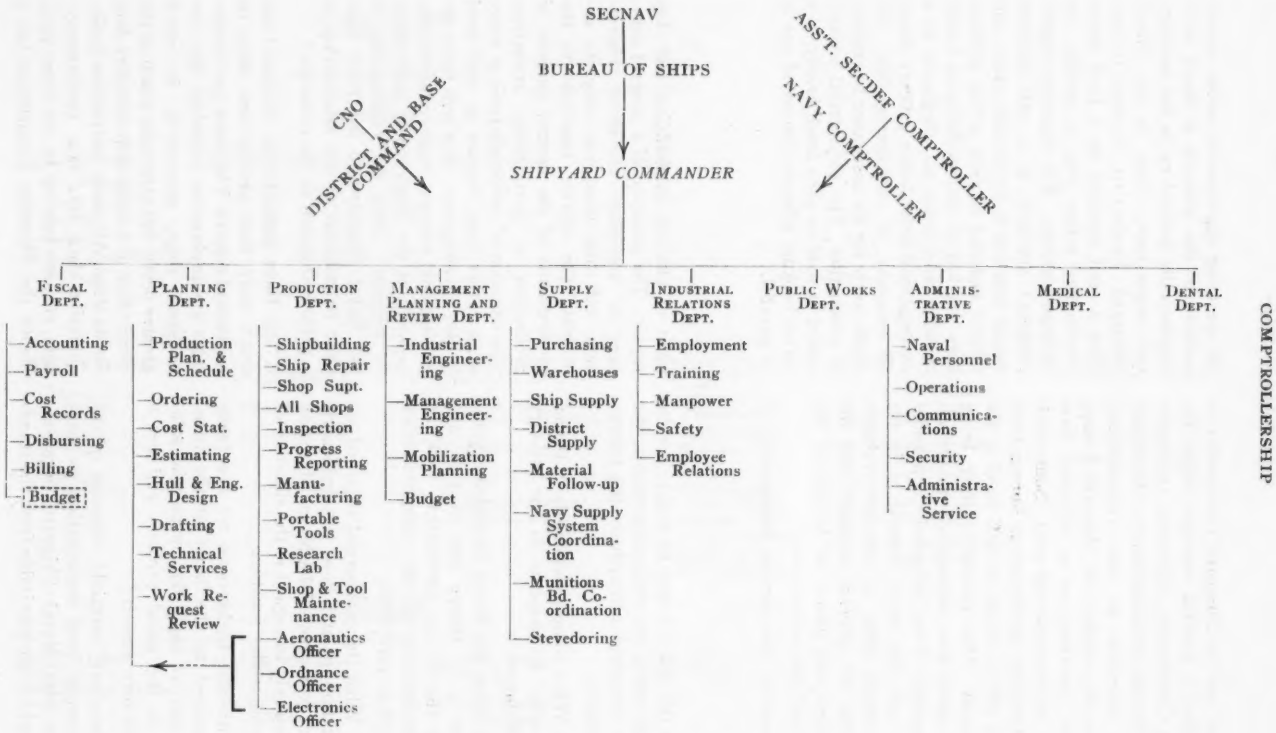


Fig. 2.—Standard Naval Shipyard Organization.

considerable direct responsibility to the ship as well as to the Production Department. The Supply Department likewise is the mail order house, the grocer, the haberdasher, and the ship chandler for the visiting fleet units. Frequently also the Shipyard must serve as harbormaster, stevedore, hotel keeper, telegraph office, warehouseman, salvage company, paymaster, transit company and fuel depot for the benefit of fleet units. Virtually every part of the yard organization must be oriented to *Fleet Service*. Ship construction and repair are major functions, but others are highly important and coordinate. Possibly then the Commander, as functional general manager for the Bureau and the Base Commander, cannot divorce himself from routine contact with all the operating departments, which in a private shipyard are coordinated by an executive below the President, without at the same time divorcing himself from the primary mission of the Shipyard, i.e., to see proper service rendered the Fleet. The primary responsibility of the President of the commercial yard, on the other hand, is to conduct profitable operations for the benefit of the owners and it is highly fitting that his full talent be devoted to this objective rather than to the customer's every whim.

But for further exploration of the subject let us suppose that the Shipyard Commander were furnished a general manager and did divorce himself from the close supervision of his service and production departments. He, then, like the president of a commercial yard, would be available to give a major portion of his attention to the comptrollership phase of management. What situation would confront him?

The president of the commercial yard bases his business administration primarily on his immediate staff which (in Fig. 1) comprises the accounting division, the estimating division, the treasurer and the legal division. He has considerable freedom of action in these fields. He can require the accounts to be kept to serve the function of management only, with little outside responsibility other than to satisfy the owners and the Board of Directors that operations are profitable, assets are not being dissipated, and that a satisfactory cash position is maintained. He can expect the estimating division to establish (for each job to be undertaken) a safe price to bid on the proposed contract, *after* detailed specifications are in hand defining the scope of the work for which the yard is to accept responsibility. These estimators are key personnel who through wide experience and keen judgment can sense what the traffic will bear as well as what the shipyard's situation will make the job cost. In repair yards, especially, both factors are quite variable and the game is fairly speculative. The treasurer's job is to maintain custody of the cash and other liquid assets, to obtain credit and insurance and to make sure the *rates* of income and outgo on specific contracts are properly in balance. The legal branch makes sure that the agreements made with customers and suppliers (unions) are accurately and tightly drawn so that neither tax, nor equity, nor labor codes are violated and that the shipyard is adequately protected.

The Shipyard Commander, on the other hand, has an accounting system in which the preponderant effort is devoted to extraneous accounting problems such as are necessarily introduced by the complexity of the appropriation structure, the civil service system, the Navy Supply System, the apportionment and allotment system, and the dispersed settlement of accounts. He is handed manuals to follow by higher authority. While the Industrial Fund accounting scheme improves the usability of data collected for management, it still is a system imposed by higher authority and superimposed on an already top-heavy overhead.

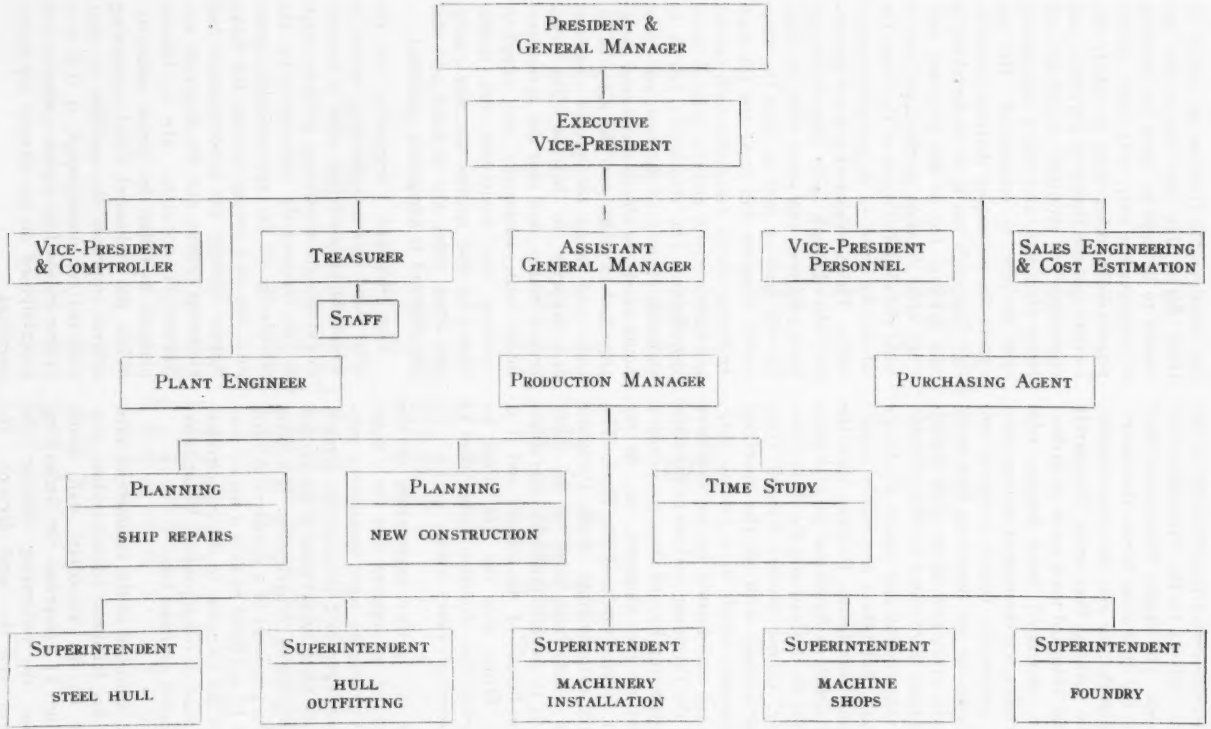


Fig. 3.—Organization of Newport News Shipbuilding & Drydock Co.

For the contract estimators the Commander has little use. The estimates which correspond in nature to those made at the presidential level in a commercial yard, that is, the ones which determine the total value of the contract, are made outside the Naval Shipyard—at Bureau level or above—and usually without benefit of detailed analysis of work specifications since these are rarely available far enough in advance. In other words the Commander seldom makes contracts, enters no competitive negotiations and does not control his own workload. He is assigned the work irrespective of price and collects afterward on the basis of returned costs. The use of standard cost estimates to assist in the control process, in contradistinction to those which merely represent an outside limit, is a technique that as yet is only in a developmental state in most shipyard work and is of questionable value in Naval Shipyards since they are saddled with so many extraneous and frequently arbitrary requirements in addition to the complex industrial task confronting them in the actual construction, conversion, repair and outfitting of naval vessels.

The Cresap, McCormack and Paget Report emphasizes that performance standards i.e., the specific number of man hours of work normally expected to be expended in standard jobs, must be established before any budgetary control system can be expected to be efficient. It recommends a most elaborate, long-term program to nail these standards down. The focus of the problem is not on a high administrative level but in the shops. The recommended program has been put into effect but progress is slow. The multiplicity of more urgent problems which beset the management of Naval Shipyards diverts the attention which can be devoted to such a program to the point where the results will probably never get consolidated before a "hotter" program supersedes it. Direct and indirect costs vary so much with the small physical interference problems and concurrent workload aboard naval ships that standards are treacherous. The standard may be wholesale and the job retail. It is not unusual that five dollars' worth of work takes a hundred dollars to get at. Or for lack of a five-dollar part a thousand-dollar delay is incurred. In commercial vessels standard parts and open design reduce these costs—in naval design space is at great premium, units are jammed together, and everything is custom-built. That's why we have had Navy yards since the eighteenth century. Otherwise there is no assurance the job can be accomplished at all, much less at a standard price and in a standard time.

It is unnecessary to go into detail to demonstrate that the treasurer function and the legal function in the Naval Shipyard, like the accounting function and the estimating function, are quite different from the parallel functions in commercial yards. The functions of a Shipyard executive are quite different from those of commercial yard executives. The differences result in each case from certain basic situations, namely:

a. Whereas the private shipyard is a self-generated and controlled activity responsible for its own external affairs, the Naval Shipyard is merely a unit in a complex of directive systems, lacking entirely in self-generation and possessing locally only very limited internal control.

b. Whereas the objective of the private shipyard is to make money for its owners through advantageous use of its productive facilities, the mission of the Naval Shipyard is to render comprehensive logistic service to our Fleet. As international affairs progress, this becomes an increasingly diverse and complex undertaking involving coordination with many foreign navies, and with new technical developments afield from conventional marine installations.

c. Whereas financial success makes or breaks the commercial shipyard, it is as inappropriate a primary measure of the Naval Shipyard as it would be of a church, or of an air-sea rescue group, viz: preeminent consideration of funds as a measure of operations negates the whole enterprise. The ideal of service can be subordinated only at the risk of its complete elimination.

VII.

The writer has undertaken to identify and discuss the implications and limitations of the comptrollership concept in the operation of Naval Shipyards. While this brief paper can in no way pretend comprehensive coverage of the subject, the study it represents appears to warrant certain pertinent conclusions. These may be summarized as follows:

a. That the Comptroller, as installed experimentally at Philadelphia Naval Shipyard, falls well short, in authority and responsibility, of the staff officer visualized in the basic comptrollership concept.

b. That the experience of private shipyards would indicate the necessity for assigning the comptrollership responsibility at executive rather than staff level to be effective in shipyard management.

c. That unless considerably greater freedom of action is allowed the Shipyard Commander, and considerably greater authority and responsibility is to be delegated to the field level in the Defense Department, the implementation of the comptrollership concept at field level will be ineffectual.

d. That the current congressional emphasis on centralized control of our military forces and consolidation of their logistic undertakings is basically inconsistent with the delegation of authority necessary to successful implementation, at field level, of the comptrollership concept.

e. That the present Bureau of Ships-Shipyard organization is the result of many years of intelligent effort in a field of endeavor in which the problem of administration is unique, and for which the system of organization must be custom-built.

f. That the present mission of the Shipyards, the nature of the shipbuilding and ship repair industry, the character of modern naval forces, and the importance of the exercise of sea power to our National Security *being what they are,* the present Bureau of Ships-Shipyard organization constitutes an adequate set-up to handle the duties assigned.

g. That the possibility of useful exercise of comptrollership appears greater at the service-wide level than at the field level, the present conduct of Military Sea Transportation Service operations being an example.

h. Such being the case the logical point for emphasizing the installation of effective comptrollership would be in the Bureau level rather than in the Shipyards.

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Data upon which the paper is based have been drawn primarily from the following sources:

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IV—Letter dated 10 December 1951, from Comptroller of the Navy to Chief, Personnel Classification Division, U.S. Civil Service Commission.

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TURBOCHARGING

ACKNOWLEDGMENT

This is an excerpt from an article titled, "Development of Buchi-Turbocharging," by DR. ALFRED J. BUCHI, of Winterthur, Switzerland, which appeared in "Schweiz-Bauzeitung," 1952, Numbers 16, 17 and 18. It was translated from the original German by MR. E. C. MAGDEBURGER of The Bureau of Ships.

First will be considered simple supercharging of internal combustion engines by exhaust gas driven turbochargers. The presentation is so arranged that the influence of all factors is easily recognizable. The principal factor characterizing a supercharged engine is obviously the pressure level of the charging air. Therefore all the other influences investigated are presented as functions of the pressure ratio of the charging air.

The size of the engine influences the possible and allowable increase of engine output, therefore the calculations to be presented were made for an engine of medium cylinder dimensions and of 6.5 m/sec = 1535 ft/min piston speed. The atmospheric pressure was assumed to be equal to 1 ata = 14.2 psia and the temperature 27°C = 80.6°F. The change in efficiency of turbochargers with rising pressure ratio was considered as well as the variation in charging air output while retaining the scavenging flow-time-areas constant. Also considered were: the heating up of the air charge in the blower and the cooling of the air charge (if such exists); pressure losses in the air cooler; the heating of the air charge between cooler and inlet valve closing at the beginning of compression; the effect of work for the change of gas at different charging air pressure ratios and efficiencies of the turbocharger; change in friction losses. All calculations were made by keeping certain exhaust gas temperatures beyond the exhaust valve constant, which approximately corresponds to a constant thermal load on the engine parts. Figure 1 shows a comparison between a conventional four-cycle diesel engine with a pressure ratio of 1.0 (unsupercharged) and the possible increase in power output as a function of the pressure ratio up to a value of 4.0 (highly supercharged engine). while retaining exhaust gas temperature at the exhaust valve as 410° to 420°C = 770° to 788°F. This could serve as a limiting value for engines in continuous full power operation, as in ships and certain types of land plant. In this picture in addition to effect of pressure ratio is indicated the influence of the cooling of charging air, as well as that of scavenging the combustion space with this air, either separately or in combination. The heavy lines represent the possible increases of output for engines

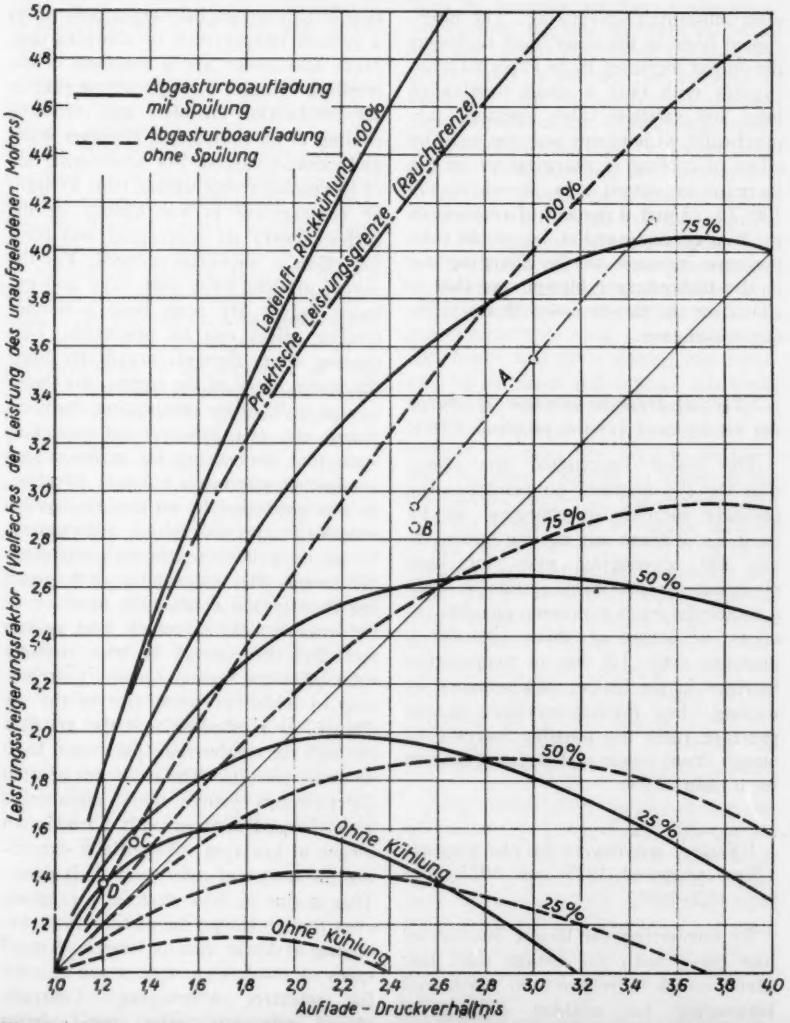

Fig. 1. Output increase vs pressure ratio, for four cycle turbocharged engines with and without scavenging for 5 stages of intensity of air charge cooling atmospheric pressure - 1.0 ata=14.2 psia; air temperature - 27°C=80.6°F, temperature of gases at the exhaust valve - 410 to 420°C=770 to 788°F; piston speed - 6.5 m/sec=1535 ft/min; percent of heat of compression removed by cooling—0, 25, 50, 75 and 100%

Abscissa is charging pressure ratio.
Ordinate is output increase factor (multiple of unsupercharged output).
Solid curves = with scavenging
Broken curves = without scavenging
Ladeluft - Rückkühlung = charging air cooling
Praktische Leistungsgrenze = smoke limit
Ohue Kühlung = without cooling

with substantial scavenging. The interrupted lines on the other hand represent the output increases to be expected from engines with only a small overlap of inlet and exhaust valve openings, i.e. practically without any scavenging. The effect of cooling of charging air on the increase in output was presented for 100, 75, 25 and 0 percent of removal of the heat of compression, i.e. of the temperature increase of the charging air in the turbocharger blower and that is shown for the two cases—with and without scavenging.

Effect of pressure increase of charging air by itself (Initial proposal 1905).

The lowest interrupted line shows that for the assumed temperatures the pressure increase of charging air by itself, i.e. without any cooling and without any scavenging, even for high charging air pressures results in only a relatively small maximum possible increase of output of about 15% for a pressure ratio 1.8 due to temperature increase in the blower, not removed by cooling. For further increases of the pressure ratio the possible increase of output drops again and is equal to zero for a ratio of 2.4.

Effect of scavenging by charging air (First proposed 1915 and 1925, first tests 1926-1927).

By comparing the lowest interrupted line curve with the lowest solid line curve, which corresponds to substantial scavenging but without cooling of charging air, the important effect of scavenging together with rise in charging air pressure on increase of output is easily recognized. For a pressure ratio of 1.8 it amounts to 60%. Further increase of pressure ratio again results in gradual drop of output. This means that scavenging is increasingly effective in raising engine output only up to a certain temperature of charging air. More and cooler air is retained in the working cylinder through scavenging of the combustion chamber and intensive cooling of all combustion chamber walls and exhaust valves. For scavenging air of increasing temperatures (due to higher compression in the blower of the turbocharger) its scavenging and cooling effect is obviously reduced. For the period of time when both inlet and exhaust valves are open only a smaller cooling effect can be produced. This cooling effect depends manifestly upon the piston speed of the engine, the thickness of walls of the combustion chamber, piston, etc. It is however not correct to state that scavenging for turbocharged combustion engines is not very effective, as was expressed by an erudite English automotive engineer who is unfortunately not as well versed in turbocharging. He forgets that scavenging air by passing through the combustion chamber of the engine picks up much heat energy and that this energy is later usefully released in the turbine thereby contributing to added pressure rise of the air charge. It is obvious that the air flow through the combustion space must have no short circuits. The existence of such short-circuits proves many automotive turbocharged engines with a maximum torque at low rpm substantially exceeding the torque at maximum shaft speed. This is due to less wasteful air speeds even though the period of time for scavenging at lower rpm is longer. Not all types of combustion spaces are suitable for effective scavenging. Centrally placed telescopic inlet and exhaust valves proposed by the writer are especially suited for intensive scavenging. Centrifugal and axial blowers possess ideal characteristics and development possibilities especially for combination with gas turbines into a simple turbocharger unit and must not be neglected.

Effect of cooling of the charging air (First proposed 1905, first tests 1911-1914).

Both of the above treated methods of turbocharging have demonstrated that without cooling of the charging air, assuming that a definite exhaust gas temperature out of working cylinders must be maintained, no increase in output is possible after a certain pressure ratio for charging air is reached. The effect of cooling of the charging air on the increase in engine output is considerable. The second lowest interrupted line shows for instance that with a pressure ratio of 2.1 removal of only 25% of the heat of compression results in 42% increase in engine output as compared with the previously named 15% without cooling of the charging air. The second lowest heavy line, on the other hand, for the same amount of cooling but combined with intensive scavenging permits a 98% increase in output for a pressure ratio 2.2. The lines above refer to a more intensive cooling—50, 75 and 100% of the temperature rise in the charging blower over 27°C = 80.6°F, the temperature of the atmospheric air. With 50% cooling, the power output can be increased 89% for a pressure ratio 2.9 without scavenging and 165% with scavenging; with 75% the corresponding values are 195 and 306% for pressure ratios 3.8 and 3.7 respectively.

Both curves of rising output for 100% cooling, with and without scavenging are also shown and indicate some very large increases possible, as for instance, for a pressure ratio of 2 with scavenging the output can be increased 3.8 times. There is therefore every reason to *cool the charging air as much as possible.* The 100% cooling however is practically almost excluded from consideration because of difficulty to provide it as well as for a purely economic reason—dimensions, weight and price of the required coolers. Furthermore it must be remembered that in almost all combustion engines as well as in all coal and liquid fuel firing furnaces the upper limit is set by the inability to burn all of the air required by combustion without smoke. This limit is shown by the dot and dash curve, second from top, for 100% cooling and corresponds to an air excess coefficient of 1.3 as compared with the theoretically required 1.0. This corresponds approximately to modern diesel engines with conventional combustion chambers and present type of injection valves for liquid fuels. In gas engines this limit for excess air is still lower and their output can therefore be increased still further. However a different limit of output increase then becomes effective, the temperature of the process becoming too high to be tolerated by parts exposed to them in the combustion engine or the turbine, thus creating a new limit to output increase of the combined unit. Thus it is up to metallurgists particularly to develop new materials to withstand higher process temperatures. The cooling of the charging air should include intercooling during the compression process so that the power required for it be reduced thereby reducing the needed output of the exhaust gas turbine and improving the combined efficiency of the whole process.

Some outstanding results in the development of the exhaust gas turbocharged engines are also shown in Figure 1. Line A connects three values from the tests at Sulzers during 1911-1914, where a charging pressure ratio of 3.5, not yet reached by the industry was tested in an exhaust gas turbine. The temperature of the exhaust gases leaving the exhaust valve of this engine was about 100°C higher than assumed for calculation of Figure 1 (510°C = 950°F). It is justified however to use the results for comparison because the back pressure used was much higher than usual in pure turbocharging, to which all other test results are referred.

Besides the test unit was a comparatively small single cylinder engine with air injection of fuel which also made it harder to obtain results. The engine operated with a very intensive, almost 100%, cooling but without any scavenging. Since the back pressure was set higher than the charging pressure, there was a re-expansion of combustion gases in the working cylinder itself and consequent reduction of the intake of compressed charging air.

Point B represents the output factor of the recently tested MAN engine K6V 30/45 with a charging pressure ratio of 2.5 corresponding to exhaust gas temperatures assumed for Figure 1. The engine worked with a very intensive, presumably over 75%, cooling of the charging air, but with relatively weak scavenging. Point C shows the output factor of a Sulzer turbocharged four cycle engine, 8 cylinder 500 x 700 mm operating at 240 rpm with about 50% scavenging. The test result (for 1.33 charging pressure ratio without cooling) is therefore above the heavy line curve for 35% scavenging without cooling. Point D represents the output factor of a turbocharged MAN six cylinder engine with scavenging to suit assumptions of Figure 1 without cooling. The operating point fell exactly on the curve for scavenging without cooling. For better orientation a thin line P has been traced on Figure 1 corresponding accurately to output increase proportional to ratio of charging air pressure to atmospheric pressure of 1 kg/cm². It indicates at a glance when greater output increase occurs than corresponding to the pressure increase of this proportional line alone. Of the interrupted line curves, i.e. those indicating output increase without scavenging, only the curves for over 50% cooling are above it, while for substantial scavenging but without cooling of charging air the output increase factors are above it for all pressure ratios above 1.58. This shows how important is scavenging especially for the many cases when no cooling or very little of it for some reason or another can be provided.

Effect of temperature of exhaust gases.

Figure 2 shows how much the output increase is affected by the limiting gas temperature at the exhaust valves. As already mentioned, this temperature

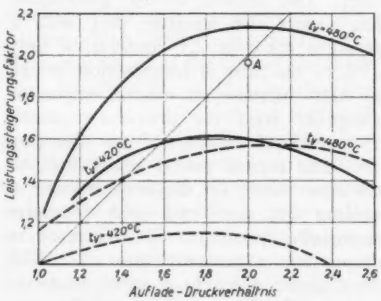

Fig. 2 Effect of limiting gas temperature on output increase for different pressure ratios with and without scavenging.
Abscissa is charging pressure ratio. Ordinate is output increase.

must be held to relatively low value for ship engines and some stationary ones working continuously at full load. This is particularly important for medium and large engines having thick combustion chamber walls of relatively high temperatures with hot spots when directly exposed to flowing hot gases. For smaller engines having thinner combustion space walls and especially those that carry heavy loads for short periods as in locomotives and automotive applications, higher process and exhaust temperatures and therefore higher outputs are acceptable, because there the cooling effect is much better from internal scavenging as well as through ex-

ternal cooling of the charging air. Figure 2 shows the gain in output increase factors when the exhaust gas temperature is increased to 480°C = 986°F or compared to 420°C = 788°F assumed for Figure 1. Here also the engine with scavenging (heavy line curves) gives a substantially higher output than the one without it (interrupted line curves). Maximum output for engine without scavenging—55.73%—is reached with a pressure ratio of 2.2 and with scavenging it rises to 113.5% at a pressure ratio of 2.0, which is an increase of 26% in output with 10% lower pressure ratio. The blower of the turbocharger can produce even lower pressure when using scavenging but must be of larger dimensions for larger volume of air to be handled.

As proof of the above point A was added to Figure 2 representing the 2000 SHP 16 cylinder Alco 9 × 10½ locomotive engine of 1000 rpm which for a pressure ratio 2, corresponding to so-called high pressure charging, develops at 100% output increase. The exhaust gas temperature for this engine is 480°C = 896°F. Point A is slightly under the curve for 480°C because the scavenging of this engine is less (about 20%) than the basis for this curve.

Effect of turbocharger efficiency.

The efficiency of the turbocharger has also a substantial influence on the possible increase in engine output as indicated by Figure 3 for engines with scavenging but without cooling of charging air for three combined (blower and turbine) adiabatic efficiencies of 55, 65 and 75%. Obviously the constant efficiency as drawn can not be obtained from a single turbocharger of a given design for all pressure ratios and output increases. But it is assumed that it is possible with a given type of construction for a given charging air pressure ratio. The shape of the curves

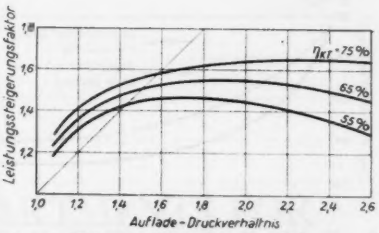

Fig. 3 Effect of combined efficiency of turbocharger on output increase for different pressure ratios with scavenging.
Abscissa is charging pressure ratio.
Ordinate is output increase.

indicates however that the possible output increase depends materially on the efficiency of turbocharger as was already indicated by Figure 1, which is based on a combined efficiency of turbine and blower of about 63%. For a pressure ratio 1.6 the output increase factor increases from 1.46 to 1.58, i.e. by about 9% and for a pressure ratio of 2.2 even by more than 17%, when the efficiency of the turbocharger is 75% instead of 55%.

Effect of turbocharging of fuel consumption.

In combustion engines the fuel consumption is of greater importance especially for longer periods of operation. Figure 4 shows how fuel consumption varies with pressure ratio of charging air from 1.0 to 2.6. A 75% cooling of the charging air was assumed, which corresponds, generally speaking, to a practically attainable maximum for a ship installation for instance. It was also assumed that the engine drives its own auxiliaries such as fuel, water and lubricating oil pumps. A substantial reduction in specific fuel consumption is indicated with rise in pressure ratio, as was already shown by pioneer tests at Sulzer Brothers. For our basic assumptions the fuel consumption drops from 178 gr =.398 lb/BHP hr to 144.5 gr

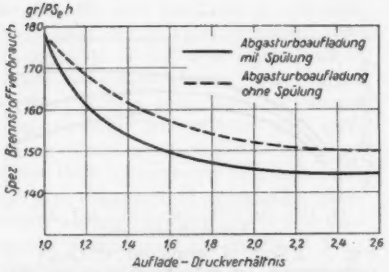

Fig. 4 Effect of turbocharging on specific fuel consumption, for different pressure ratios with and without scavenging, all auxiliaries included.

Abscissa is charging pressure ratio.
Ordinate is specific fuel consumption.
Solid curve is with scavenging.
Broken curve is without scavenging.

= .323 lb/BHP hr for a pressure ratio 2.6 in turbocharged engine with scavenging and to 150 gr = .336 lb/BHP hr without scavenging.

The above analysis shows that turbocharging can in many respects be much improved and developed. High pressure charging is to date used only in rare individual cases (Alco locomotive engine and new MAN test engine). Stronger constructions are needed for higher working pressures and, because technically very promising results are indicated, progressive industrialists of vision and courage will be forthcoming to back this new development. These new engines must show small flow, friction and heat losses and efficient form of combustion space, utmost cooling of charging air and efficient scavenging; their turbochargers must extract as much heat energy as possible from the exhaust gases in their turbines and compress the charging air with minimum power in their blowers. To comply with these specifications many problems must be solved by the progressive combustion engine science for the four-cycle as well as two-cycle engines. For high altitudes it is also essential to raise the possible engine output. And in addition to all of that to preserve and improve the competitive status of the combustion engine a minimum weight and cost of all parts of the combined plant must be secured.

TESTING COMPARTMENTS FOR TIGHTNESS BY USE OF COMPRESSED AIR

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EDITOR'S NOTE

The complete article by Admiral McShane is too long for publication in a single issue of the JOURNAL. *Parts I, II, and III were published in the May 1952 issue of the* JOURNAL *and Parts IV, V, and VI were published in the August 1952 issue. Parts VII and VIII are published below. The Appendices will appear later.*

PART THREE

REFERENCES

(a) Bureau of C & R pamphlet, "Air Tests of Compartments of Vessels of the U. S. Navy," reprint dated January, 1922.

(b) Bureau of C & R letter S-29-8(TB) EN7/A2-11 of September 20, 1933, to Commandants, all Navy Yards and all Superintending Constructors.

(c) Bureau of C & R letter A10/S-29-8 (C & DC) of August 20, 1935, to Commandant, Navy Yard, Norfolk, Va.

(d) Norfolk Test Serial No. 188—"Air Tests of Compartments—Investigation and Experiments."

(e) Bureau of C & R letter S29-8 (C & DC) of June 1, 1938, to Commandant Navy Yard, Philadelphia, Pa.

(f) Bureau of Ships letter S29-8 (Dz) EN28/A2-11 of March 11, 1941, to Commandants, all Navy Yards and all Supervisors of Shipbuilding.

Appendices

I. Mathematical Analysis.

II. Probable Accuracy of Past Determination of Aperture Area.

VII—PRACTICAL CRITERIA OF TIGHTNESS

The only sure test of the tightness of a compartment is to fill it with the fluid it is designed to retain. The substitution of other fluids introduces some element of doubt. For instance, a watertight space may leak oil, an oil-tight space may leak air. The relative "searching" power of the various fluids possibly is a matter of differing surface tensions or viscosities. Thus, when air is the testing medium there arises the question "How much air will leak from an oil-tight or watertight compartment?", in other words, "What is the criterion of watertightness or of oil-tightness or of gasoline-tightness when air is the testing medium?"

Method of reference (a)—This method assigned "allowable" apertures for each type of fitting and for representative ship structure. These "allowable" apertures represented the aperture area which existed when the fitting or structure in question was "just watertight." With that data it was possible to assign to any given compartment the total "allowable" aperture and then calculate on the basis of the known volume and test pressure, an "allowable" drop. It is implicit in this method that if the "observed" drop is equal to or less than the "allowable" value the compartment will be watertight. Fundamentally this method provides an excellent criterion. Although it may be argued that each fitting may not contribute to leakage in proportion to its "allowable" aperture and that a single undiscovered aperture may be responsible for a major part of the "observed" drop, it is not likely that such would be the case if the compartment had been examined carefully prior to observing the drop. The real objections to the method are:

(a) the difficulty and great labor of determining "allowable" apertures. Changing designs require the adoption of new values based on experiment or, less satisfactorily, on estimate.

(b) the uncertainty of the precision with which "allowable" apertures have been determined. For instance, diaphragms such as W.T. doors are likely to give variable results when tested, particularly at higher pressures.

(c) most important, the really great amount of time and labor to tabulate fittings, calculate boundary area and volume and calculate the "allowable" drop.

Other methods—In order to reduce the large volume of calculations various expedients have been adopted in the past. It was noticed that for compartments of a given functional classification, i.e., tanks, storerooms, magazines, etc., the number and character of the fittings which contributed to air leakage were roughly the same. Therefore, it could be assumed that the total "allowable" aperture for each space in a given classification was a function of the type of the space. For instance, the follow-

ing method was employed at the New York Shipbuilding Corporation:

(a) for each compartment the boundary area was calculated and the major closures (doors, hatches, manhole covers, etc.) were tabulated.

(b) the "allowable" aperture for these boundaries and fittings was ascertained and formed the basis for calculating the "allowable" drop for strength and tightness tests.

(c) for completion tests, the additional aperture for piping, cable, valves, etc. was assumed to be a fixed additional percentage of the aperture in (b) above. The additional percentage varied with the type of compartment and was an empirical value based on past experience. In general, the "allowable" drop for completion tests was less than would have prevailed if the complete calculation for each of the fittings actually installed had been employed.

(d) if it proved impossible to attain the "allowable" drop thus calculated, the compartment was checked to determine the fittings actually installed and a new calculation was made based on the "allowable" apertures for the fittings actually installed.

The experience of years seemed to indicate that the original aperture values given in ref. (a) were too liberal and that, possibly, the pressure versus time curve was not correct. In consequence, the Navy Yard, Norfolk was requested to investigate the entire question. The result was a report, ref. (d), which proposed new aperture values and a new curve to be employed with them. There is no indication that these new data were ever adopted. The report in ref. (d) did not propose any new *method* for criticizing tightness.

Investigation by the Navy Yard, Philadelphia—Despite the labor being expended to calculate allowable drops the results obtained in practice continued to show the need for a revision of method. Accordingly, by ref. (e) the bureau requested the Navy Yard, Philadelphia to undertake an analysis of the actual air test results of a number of ships with the following objects in view:

(a) to determine if some correlation existed between observed drop and test pressure or between observed drop and compartment volume.

(b) to develop new criteria of tightness which would reflect the results of experience and simultaneously reduce the labor of assigning "allowable" drops.

The yard analyzed the data for a large number of ships and found no reasonable correlation between drop and test pressure nor drop and volume. As a result the yard proposed an entirely new criterion of tightness in which no consideration of test pressure nor volume enters. The method is as follows:

(a) compartments are grouped according to function, i.e., storerooms, magazines, living spaces, etc.

(b) for each group several drop "brackets" are assigned and a specified minimum cumulative percentage of the total number of compartments is assigned to each drop "bracket."

(c) for each group a maximum drop in 10 minutes is specified.

This method was adopted by ref. (f).

The method has the great virtue of being very simple to apply. It eliminates the need for almost all calculation and it can be understood readily by test personnel. If *air* tightness is to be the standard the method promotes it by encouraging the attainment of a high proportion of low drops. On the other hand the method is open to criticism from both practical and theoretical standpoints.

From a practical point of view the first objection is that no criterion for

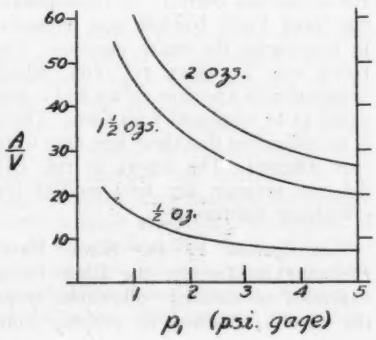
strength and tightness air tests has been provided. Presumably the same standards are to be employed. Second, the scheme is indefinite as far as any particular compartment is concerned. For instance, in a CL with a total of 52 Ammunition and Magazine spaces the requirements are:

½ oz. or less	80%	(42 compartments)
1½ ozs. or less	18%	(9 compartments)
2 ozs. or less	2%	(1 compartment)

The question immediately arises as to which of the 52 shall be assigned the 2 ozs. drop and which 9 the 1½ ozs. The practical answer is to strive for ½ oz. drop in all cases even though no "useful" tightness may be gained. The other alternative is to proceed normally until one compartment which is difficult to make tight shows up and then accept a 1½ oz. drop on it. In the next difficult space 1½ ozs. will be allowed and so forth. Thus, the great advantage of the method-simplicity—is somewhat impaired by the indefinite nature of the criterion. Third, the method is not flexible in regard to future changes as dictated by experience. Revisions require the maintenance of somewhat awkward tabulations and a lengthy statistical analysis.

The theoretical objections to the method are more important. The fundamental basis of the method is the classification of the observed drops on a number of ships. Those drops were subject to wide dispersion due to the inherent errors discussed in Part V and the differing standards of tightness discussed in Part VI. In particular, the different standards must have had an important effect on the percentages assigned to the drop "brackets". The typical examples given in Part VI show a striking lack of consistency not only between yards but between sister ships at the same yard. No systematic variation in observed drops is apparent. Therefore, had certain of the ships which were studied in the Philadelphia analysis been eliminated, it is quite probable that different percentages would have ensued. Furthermore, the basic data applied to ships having particular volumes of compartments tested at particular pressures. If future ships depart materially from these proportions it is questionable whether the same percentage standards should be applied. On the whole it would seem that the percentages which were observed were fortuitous and do not form a sound criterion for future ships. Indeed, the method of analysis really gives a false picture of the conditions which existed in the past inasmuch as it adopts the variable factor of drop as the basis instead of the more stable factor of aperture.

In neglecting all consideration of both volume and test pressures the Philadelphia method rejects all rational considerations. As an example, take the present allowances for Ammunition and Magazine spaces on cruisers. For the sake of argument it will be assumed that n will be unity. The graph here shows the corresponding "allowable" A/V values for the range of pressures



in which completion tests will be conducted. For a given compartment the ordinates show the relative value of the allowable aperture. In addition to the fact that an extremely wide range of tightness is permitted for a given compartment (i.e., a given value of V) it is most significant that as the test pressure is increased the allowed aperture is decreased! Surely, there is no logical reason to demand that compartments be tighter merely because the test pressure is increased.

Suggested Method—There probably is no brief and simple method of assigning "allowable" drops which will be as rational and as specific as the method of ref. (a). That *method* cannot be criticized on the grounds that it did not demand adequate tightness because greater tightness could have been required merely by reducing the "allowable" aperture. Its objectionable feature is the labor involved in its employment. If other methods of assigning "allowable" drops are to be devised they should have an equally rational basis. It must be repeated that tightness is determined by aperture area and if new criteria are to be devised based on the results of past experience the basis of the method should be aperture area, not observed drops in pressure.

It is reasonable to assume that, in the past, compartments have been made adequately tight; i.e., the aperture area which existed when the compartments were passed was small enough to be acceptable. Therefore, a logical method for devising new criteria is:

(a) determine the aperture areas which existed in the past in satisfactory compartments.

(b) correlate these data with some characteristic of the compartments which will define their tendencies to leak air.

The first step would indeed be an arduous task if it had to be performed by the method of ref. (a) but by the use of graphical solutions the task is brought within practicable bounds. When the volume, test pressure and observed drop are known the determination of A is a simple process.

The selection of a simple characteristic of compartments which will define their tendency to leak air without recourse to the scheme of ref. (a) requires some broad assumptions. One possible approach is as follows. The sources of air leakage may be classified into two major categories:

(a) the fittings such as doors, hatches, valves, piping, cables, etc., the number of which, roughly, is a function of the type of compartment, i.e., tank, magazine, storeroom, etc.

(b) the welded or riveted joints in boundary structure the extent of which, roughly, is a function of the boundary area.

Thus, for a given type of compartment on a given class of ship (and possibly on all classes of ships) it might be reasonable to expect that the past attainable aperture area was a characteristic function of the boundary area. It is likely that by plotting A versus S (boundary area) for past tests of compartments which were considered adequately tight a value of A/S could be assigned which would define an acceptable limit of tightness. Such a criterion would demand the same "tightness per sq. ft." for large and small compartments of a given type.

Such an analysis would require the collection of boundary area data for past tests and it would be a major task to assemble it. However, it would not be unreasonable to commence the collection of such data on ships now under construction and prepare an analysis for future use. The analysis could be expedited greatly by the adoption of methods as follows:

(a) for a *rectilinear* compartment

$$\frac{S}{V} = \frac{2(L_1L_2 + L_2L_3 + L_1L_3)}{L_1L_2L_3} = \frac{2}{L_1} + \frac{2}{L_2} + \frac{2}{L_3}$$

Where L_1 and L_2 and L_3 are the dimensions of the compartment. This equation can be solved quickly by use of a table of reciprocals. Sufficient accuracy is attained by taking dimensions from plans to the nearest foot. If a compartment is not rectangular it is accurate enough to take the average of each of the major dimensions.

(b) determine A/V by graphical solution from the known drop and test pressure.

(c) plot S/V versus A/V or divide A/V by S/V. In either case inspection of the data would reveal whether a reasonable acceptable limit of A/S could be assigned to various types of compartments.

Proposed method—In the absence of collected data on boundary area for past ships and in view of the considerable effort necessary to assemble the information, it is desirable for the immediate future to provide some other characteristic of compartments which will define their tendency to leak air. An approximate, but not completely untenable basis, is compartment volume, the data for which was assembled in connection with the Philadelphia analysis. Although boundary area does not vary systematically with volume it does, in general, increase and decrease with the volume. Therefore, the ratio A/V might be expected to serve as a reasonable criterion of compartment tightness.

The data on allowable and observed drops, volumes and test pressures which was used in the Philadelphia analysis was obtained from the Philadelphia Navy Yard. An analysis of that data was made in the following fashion:

(a) using the *"allowable"* drop and the assigned test pressure the "allowable" A/V was determined.

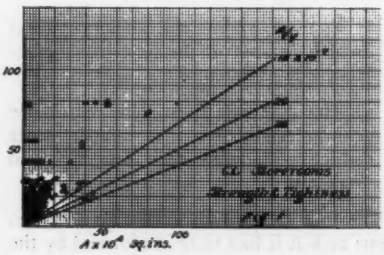
(b) with the A/V thus determined and the known value of V the value of A versus V was plotted.

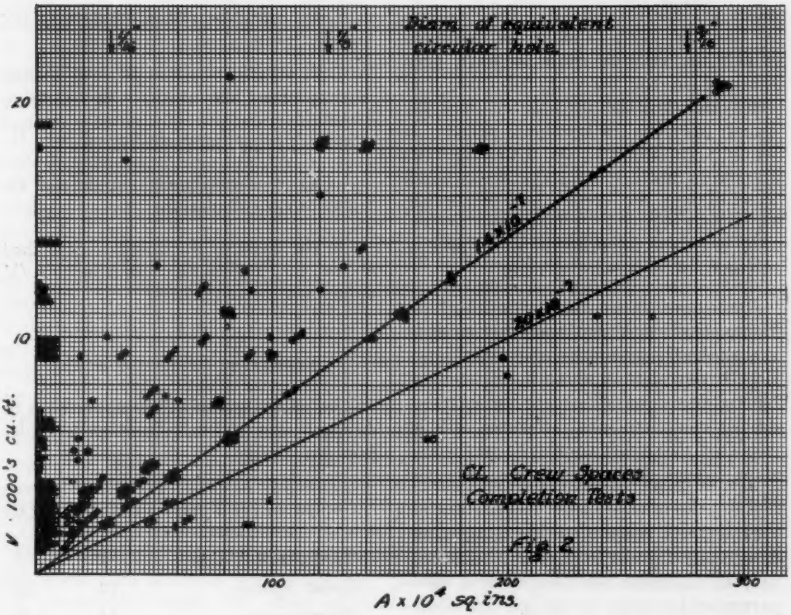
(c) the same process was used to determine *"actual"* apertures on the basis of *observed* drops and these data were plotted on the same sheets with the corresponding "allowable" aperture values.

(d) inspection of the plotted data reveals whether any reasonable correlation exists between aperture and volume.

An initial study was made using data for CA37, CL42, CL43, and CL46 with the various compartments classified according to their vertical position, i.e., all inner bottom spaces on one plot, hold spaces on another, etc. No reasonable correlation existed. A second study of the same ships was made with compartments classified according to function. In this case a reasonably orderly variation of A with V was apparent. Accordingly all the remaining data was analyzed with compartments grouped in that manner.

Two examples of the results of this analysis are shown on Fig. 1 and 2.





It will be noted that a large number of spots are the "zero" drops. In view of the inaccuracies discussed in Part V it is likely that many of the drops recorded as zero actually should have been higher.

Fig. 1 is an example of good correlation; Fig. 2 represents poor correlation. It cannot be expected that all plotted spots will be bunched closely or follow a smooth pattern; the very nature of testing procedure precludes that. To assist in visualizing the order of magnitude of the total aperture area which existed, Fig. 2 also shows the diameter of circular holes which would have areas equal to corresponding values on the graph. It is possible (although not very likely) that some of these compartments could have been accepted with a single existing aperture of the size shown.

Despite the relatively wide dispersion of the observed data the significant fact is that, in general, the "allowed" apertures and the "observed" apertures increase in approximately uniform fashion with the volume and, in general, the observed apertures are considerably less than the allowable values. Thus, a value of A/V can be assigned for a given type of compartment which is near the lower limit of "allowable" values and which past experience shows is attainable in practice. Using Fig. 2 the limiting A/V value for Cruiser Crew Space Completion Tests should be 14; from Fig. 1 the limiting value for Cruiser Storeroom S & T tests should be 14.

In the assignment of limiting values for A/V it is believed that the inherent errors in measuring drop and the different standards at various yards should be taken into account. The fact that a few yards have reported tightness of an extremely high degree is not believed to be sufficient grounds for demanding the

same performance at all yards. Rather, a limiting A/V should be assigned which the records show to have been attained in the majority of cases and yet which will be no greater than the *lower* previous "allowable" values. It would seem wiser to avoid too rigorous standards until some steps were taken to eliminate the errors now occurring from heat transfer, at least, and preferably until the adoption of more precise methods of determining drop.

The significance of a "limiting" or "allowable" A/V is about the same as the allowable apertures of former practice; it represents the minimum acceptable tightness for all except the extraordinary compartments. It would still be expected that most compartments would show actual A/V values less than the limit.

It will be noted that the assignment of a limit for A/V makes it unnecessary to calculate the volume of a compartment in order to assign an allowable drop. The allowable drop would be a function of the test pressure and time only. By standardizing the time at 10 minutes the test pressure would then become the sole independent variable.

The virtues of the method proposed here are that:

(a) it is rational in that it employs aperture area as the criterion of tightness and gives consideration to both volume and test pressure.

(b) it is consistent in that it demands the same "degree" of tightness in all compartments of a given classification.

(c) it applies to strength and tightness tests as well as completion tests.

(d) it provides a specific criterion for each compartment which can be accepted or rejected immediately.

(e) by plotting the values of A versus V a clear picture is provided of the tightness characteristics of the entire ship.

(f) it affords a simple and readily comprehensible means of judging tightness and provides an easy method of modifying the requirements.

(g) it is extremely simple and requires no calculations.

On the basis of the analysis described above the following "limiting" A/V values are recommended:

LIMITING VALUES OF A/V

The values given below apply both to strength and tightness and to Completion Air Tests:

Compartment Type	*CA, CL*	*DD*
Tanks and Voids	7	7
Crew Spaces	14	25
Storerooms	14	21
Ammunition and Magazine Spaces	17	21
Machinery and Control Spaces	17	21
Trunks	17	—

The classifications given above probably are too condensed. They were adopted because the available data were so classified. It is entirely possible that more detailed classification would result in better correlation of the observed data. For instance, "Machinery and Control Spaces" embraces compartments in which quite widely varying tendencies to leak air might be expected. Surely, certain spaces containing auxiliary machinery should be inherently more air-tight than a Plotting Room or a Distribution Room where large numbers of electric cables provide sources of leakage which are nearly impossible to eliminate entirely. With the method of

analysis proposed here a more detailed classification of compartments in accordance with their tendencies to leak air would entail negligibly increased labor either in analysis of results or application in air tests.

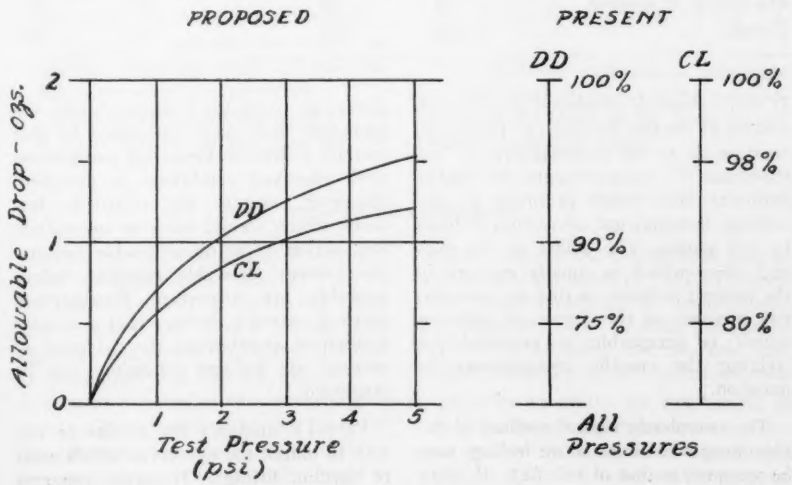
It will be noted that the table above proposes the same limiting A/V for both strength and tightness and for completion tests. This does not seem logical but that is the general nature of the evidence. It is entirely possible that more precise drop determination and the elimination of the aberrations caused by heat transfer would reveal what logically could be expected, i.e., that limits for S & T tests would be lower. The fact that such a condition is not revealed by the past data may be due in large part to the fact that the lower completion test pressures promote greater inaccuracy in drop determination.

There were not sufficient data available when this analysis was made to give acceptable values for other ship types. Very likely the values given above for cruisers will be applicable to BB's, CB's, CV's and large auxiliaries, and the values given for destroyers will apply equally well to all ships of light construction.

A representative graphical comparison of the proposed limits with those now in effect for Ammunition and Magazine spaces is given below.

The curves showing proposed values are merely the appropriate A/V curves. The difference in the character of the two methods is apparent. It is clear also that the maximum benefit of the proposed method would not obtain until drops are measured more precisely than has been the practice in the past.

It will be noted that the proposed method is based, in effect, on a curve of drop versus test pressure, whereas the Philadelphia analysis failed to find any correlation between these factors. The answer to this seeming conflict lies in the fact that, particularly with completion tests, the range of test pressures is quite narrow and on a plot of d versus p it would be difficult to notice any



reasonable correlation. When the analysis is made by plotting A versus V, however, the spread of values is much greater and correlation is noticeable.

"Extraordinary" compartments—Any analysis of air test results reveals that in the past certain compartments have been accepted which contained extraordinarily large total aperture areas. Presumably these aperture areas could not be reduced by practicable methods. Part of the explanation of these unusual spaces may lie in improper classification as previously mentioned but this is not likely to be the complete answer. When confronted by test results from such a compartment which exceeds the limit of usual tightness standards some method of judging its acceptability should be provided.

The simplest way to judge the acceptability is to obtain assurance that rigorous efforts have been expended to make the space as air-tight as practicable and then simply accept it as it stands.

Another criterion is the general idea in the present method which makes allowance for "extraordinary" compartments by allowing a small proportion of high drops in each classification. In the same fashion it is feasible to allow higher A/V values for such spaces. For instance, Fig. 2 would indicate that an A/V of 30 x 10^{-7} could be adopted as the limit for "extraordinary" cases. With this idea the following values, based on past results, show the highest usual values which have been encountered:

Compartment Type	*Completion*		*Str. & Tightness*	
	CA, CL	*DD*	*CA, CL*	*DD*
Tanks and Voids	15	20	15	25
Crew Spaces	30	40	25	35
Storerooms	30	40	25	35
Ammunition & Magazines	30	40	25	50
Machinery & Control	55	60	45	50
Trunks	55	100	50	70

If this scheme is employed it seems advisable to confine the data on limits and decision as to the acceptability of "extraordinary" compartments to higher authority than usual in order to discourage lackadaisical correction of leaks by test gangs. The defect in this general idea—which is equally existent in the present method—is that no quantitative measure of the degree of tightness which is acceptable is provided for judging the specific compartment in question.

The completely logical method of determining when unusual air leakage may be accepted is that of ref. (a). If, after failure to reach the ordinary limits, the allowable drop were calculated by that method a definite figure for comparison with observed conditions is provided. However, despite the relatively few cases which should arise to necessitate this action it is objectionable because the present allowable aperture values probably are incorrect. Furthermore there is reason to believe that a simpler method of ascertaining the existence of unusual air leakage conditions can be employed.

Part IV analyzes the results of ref. (d) to obtain the apertures which exist in specific fittings. It seems apparent

from these data that virtually uncontrollable leakage occurs in electric cables which may be responsible for a very large proportion of the drop in many cases. It is possible that merely by counting the number of electric cables which pierce the boundaries a reasonable indication of "extraordinary" conditions will be afforded. There are no data now available on which to base specific recommendations for methods of judging the degree of tightness which should be allowed but the field is open for the future.

On the whole it would appear advisable for the present to adopt the maximum A/V values stated above as defining the limit for "extraordinary" spaces. Naturally, it would be expected that only rarely would it be necessary to accept compartments with such low degrees of tightness.

Summary of Proposed Method—The method proposed here is:

(a) using the limiting values of A/V recommended above, and the specified test pressure and time the allowable drop for each compartment would be ascertained and, preferably, tabulated for the convenience of the test gang and inspection personnel.

(b) each compartment would be searched thoroughly and all discernible leaks would be corrected.

(c) the drop would be observed. If it were equal to or less than the "allowable" value the compartment would be passed immediately.

(d) if the drop first observed exceeded the allowable value reasonable additional search should be made to discover and correct leaks which previously were overlooked. If the compartment continued to exceed the "allowable" drop the data should be referred to higher authority for calculation of the existing A/V and for comparison with the values given above for "extraordinary" cases. At the same time it is believed advisable to determine the approximate number of electric cables which pierce the boundaries as a possible means of characterizing "extraordinary" compartments.

(e) as the testing on each ship was completed charts similar to Figs. 1 and 2 would be submitted to a central agency as a convenient indication of the general tightness being attained and to provide a basis for future revisions of limiting A/V values. At the same time the "extraordinary" compartments should be marked to show the number of cables existing until enough data has been gathered to indicate the feasibility of this criterion.

It is believed particularly important that efforts to obtain *air-tight* compartments should cease in all cases except, possibly, tanks and voids.

VIII—RECOMMENDATIONS

The importance of adequate tightness needs no elaboration. But, in view of the labor involved in rectifying leaks, the requirements should be *adequate* tightness and not *air*-tightness. In order to accomplish this aim the first need is to provide a criterion of adequate tightness which should have the primary characteristic of being based on rational considerations and secondarily should be specific, consistent, flexible and simple. The method proposed in Part VII meets these requirements and is recommended for adoption. The "limiting" values of A/V recommended therein are considered satisfactory for immediate use.

In order to derive the full benefit of any criterion of tightness and to eliminate useless work it is necessary that drops be measured as accurately as prac-

ticable and that the drops so measured be indications of air leakage alone. Therefore, it is recommended that the type of differential gauge described in Part V be tested and, if found practicable, be adopted.

The standards of tightness obviously have not been the same at all building yards. This situation is undesirable, at best. The fundamental question involved is whether or not *air*-tightness is the standard for which to strive. It is considered that water, oil, gasoline, etc. tightness should be attained and that *air*-tightness as a standard results in much useless work. Therefore, it is recommended that standards of "adequate" tightness be adopted and this fact be promulgated to all building yards. This can be accomplished merely by adopting the values of A/V recommended herein and instructing building yards to make no particular effort to attain greater tightness.

EDITOR'S NOTE: *Previous portions of this article appeared in the May and August 1952 issues of the* JOURNAL. *The remainder of it will be published in a subsequent issue.*

WAR ON WEAR

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Since man "wore" his first crude clothes and his first primitive tools, war on wear has been waged at an ever-increasing rate. This is understandable because, whenever and wherever the greed for consumption goods is satiated, wealth is essentially accumulated by producing capital goods, that is, goods subject by their use to damage, including wear. The stage may ultimately be reached, where the amount of capital goods reaches a ceiling at which production just offsets losses due to damage. In determining the height of the ceiling, the rate of dissipation *(inter alia,* by wear) is just as important as the rate of production.

Another way of looking at the economic problem of wear is that the amount of material removed by wear, that renders articles unfit for further use, usually is annoyingly small as compared with that of the weight or volume of the article itself. Outstanding examples are cutting implements (razor blades, knives, turning tools, etc.) and measuring gauges. Almost without exception, the loss of material through wear, possibly in conjunction with that through more or less periodic reconditioning, is minute relative to what is left recoverable as scrap. This is a fortunate circumstance, the material lost being in forms as irrecoverable as the wear dust dispersed from ploughshares into the soil. On the other hand, the labor involved in bringing back the scrap into a form suitable for the recirculation of material necessary for replacing worn articles counts far more heavily. All in all, in the wear problem the waste of energy would appear to be economically of even greater concern than the waste of material.

The conclusion to which we are inevitably led, even after due allowance for inaccuracies in estimates of the most important items of the wear budget and of their sum total, is that war on wear is well worth waging. However, there is no room for counsels of perfection when it comes to making efforts to diminish rates of wear. There is no sense in prolonging the material life of an article far beyond its economic life; this applies especially to articles which become outdated, either by engineering development still going on rapidly (e.g., metal-cutting machinery), or by changes in fashion (as in clothes).

One field of wear is characterized by the set-backs inflicted in the established type of service of the goods concerned. An outstanding example of this field is provided by the wear of that most important asset of mankind, the soil on

and from which we live; in fact, soil erosion deserves increasingly greater attention because of the steady increase of the world's population. There are also many examples of another field where engineering progress was severely hampered by wear; several among them are still with us, e.g., cavitation erosion, the wear of rock bits in the drilling of deep oil wells, etc.

Before going into strategy and tactics, i.e., the principles and methods suitable for combating wear, it is desirable to reconnoitre the theater of wear by differentiating and interrelating the various types of wear. To this end, the following definition of wear provides a useful starting point: Wear is the undesirable migration of the material of a solid surface, essentially due to the overstressing caused by mechanical forces, if these are exerted in a direct way on the surface by its continuous or repetitive motion relative to a fluid or solid in contact.

The migration of surface material may occur in two main forms. The first is complete migration, or, say, removal of surface material; this is the most radical form. In cases where there are two solid surfaces mating, material removed from one surface may be deposited on the other; even this undesirable deposition by transfer of material is included under the above definition of wear. The second form is partial migration of material, which may take place either in the form of plastic deformation or in that of rearrangement of atoms—within one surface layer as well as between it and its mating surface or other contacting medium, such as the atmosphere or a lubricant—into new physical units (recrystallization) or into new chemical constituents. The process of migration by rearrangement, into the surface material, of atoms of a contacting medium may considerably complicate the mechanism of wear involved. In this process, physical aspects such as diffusion and mutual solubility, as well as diverse chemical aspects, may enter as factors implicit in the above definition of wear.

Despite the complexity inherent in most wear phenomena, and their consequent wide diversity, they center on one characteristic in common, that is, the mechanical overstressing of the surface material. A rational approach to the problem of classifying the different types of wear consists, therefore, in classifying them according to the different ways in which the overstressing can be brought about. The various types of wear can be grouped, accordingly, into two broad classes which conform to the two possible states, either the fluid or the solid state, of the contacting medium which causes the mechanical forces.

"Single-sided" wear (or erosion), which is the first class, comprises the types of wear occurring in cases where the contacting medium is a flowing fluid; accordingly, fluid mechanics is involved in judging the forces exerted on the solid surface attacked. The only solid surface concerned generally serves to direct the flow of the fluid medium, for instance, a turbine blade directing the flow of steam, or a centrifugal-pump impeller directing the flow of water. Overstressing, and thus wear, of flow-directing surfaces is rather the exception than the rule.

One of the best-known types of single-sided wear is cavitation erosion (such as that on the blades of ships' propellers), which is caused by the impacts due to the "implosion" of cavitation bubbles in the flowing liquid. Another, closely related, type of this "liquid" erosion is well known in turbines, the blades of which are affected by the impingement of droplets present in wet steam. Fluid contact and impact are obviously characteristic of these types of erosion. A limiting case of erosion arises when the flowing medium is a powdered solid which is more or less fluidized. This case provides a transi-

tion between single-sided and double-sided wear, in that solid contact is occurring.

Double-sided wear, the second class, comprises the remaining types of wear, which are characterized by the presence of two mating solid surfaces, rubbing on each other. Here, one surface is guided by the other; thus, forces are created with serve, say, for transmitting power, as through the teeth of gears, or for dissipating power into frictional heat, as in brakes. In any case, the frictional energy is converted into heat, and the temperature rise thereby caused at the rubbing surfaces introduces an important factor determining the type of double-sided wear obtained; in fact, temperature affects the properties of the surface materials and the rate of their chemical reactions.

Besides the rise in surface temperature, the nature of the solid contact also proves useful in studying certain features of, as well as in classifying, the the types of double-sided wear. There are two kinds of solid contact, which correspond with two extreme degrees of geometric conformity of the two mating surfaces.

At one extreme, the surfaces are macro-geometrically conformal or nearly so, that is, they fit on or in each other. The two representative examples are a plane surface on another plane surface, and a convex surface enveloped by a concave one; with perfect conformity, sliding is the only relative tangential motion possible. Further, the overall shape, i.e., the macro-geometry, of the surfaces here recedes into the background, and their micro-geometry, i.e., their finish, constitutes the decisive factor in determining the nature of contact. In fact, contact takes place preferentially between summits of instantaneously opposing surface irregularities; because of the comparatively wide spacing of the summits, it is "disperse contact" that obtains. It is known from the work of various investigators that the summits tend to deform plastically, so that the pressures in the tiny areas of real contact correspond with the hardness of the softer of the two mating surfaces. At the other extreme, the two surfaces are macrogeometrically non-conformal. This —e.g., when both surfaces are convex— results in "concentrated contact," as contact tends to concentrate in one contact area. A feature common to both cases of contact is that the real contact pressures usually are very high indeed, i.e., often of the order of at least a few thousand atmospheres. One consequence of this feature is that, in both cases, overstressing, and thus wear, of surface material can hardly be avoided; this is contrary to what is normal in fluid contact, on flow-directing surfaces. Another important consequence of the high contact pressures is that, whenever sliding speeds are high enough, the intensity of frictional heating can become so great that high temperatures are generated in the contact areas.

One of the simplest types of double-sided wear is that which is characterized by the effects of frictional forces being negligible as against those of the compressive forces, repetitively or, say, cyclically, exerted by one surface on the other, and vice versa. The ensuing type of wear, pitting, thus is typical of rolling motion and, therefore, of concentrated contact; it follows that temperature rise by solid-frictional heat cannot be great. All of this is confirmed by the occurrence of pitting principally in machine elements such as rolling bearing, and at or near the pitch circle of gear teeth.

Pitting is recognized to be caused by "surface fatigue," and actually, like any fatigue, it does not develop until load has been applied for an incubation or induction period, i.e., for a critical number of cycles that depends on the magnitude of the compressive stresses exerted on the surface, and, of course, on the nature of the surface material.

Remarkably enough, it is not unusual for pitting to be arrested, so that surface deterioration does not go on to the bitter end. This is presumably owing to the strain-hardening of the surface material, which may offset the increase in stresses caused by the diminution of the bearing area remaining in between the pits. Here we encounter the self-restoring capacities of surface materials, which play a large part also in many other types of wear.

The remaining types of double-sided wear are less simple, mainly because more complex types of interaction arise; of these types, only some representative examples will be discussed.

Abrasive wear is here defined as that type of double-sided wear in which the interaction between the mating surfaces is primarily caused by their geometric interference. This interference, resulting in a "ploughing" action, may be either on a macro-scale or on a micro-scale. Macro-abrasion occurs, for example, when two mating teeth bend under the load transmitted, so that, of the next pair of teeth to be mated, the tip edge of one tooth is not correctly spaced with respect to the root of the other and, consequently, acts as a cutting edge, producing in that root a groove which is directed perpendicularly to the relative motion. After the mating tooth profiles have thus adapted themselves to each other, macro-abrasion stops. Self-control, that is, the automatic balancing of attacking by resisting factors, is here brought about in a geometric manner.

Micro-abrasion is due to the interlocking of the surface irregularities which are invariably present at solid surfaces; it can be diminished by careful finishing. The interlocking introduces a cutting or shearing action and results in grooving of the surfaces in the direction of their relative motion.

The grooves occurring in the region of pure rolling of the tooth have obviously been caused by the wear particles which, after abrading off in the neighboring regions, were forced through the former region. This phenomenon leads us to a sub-type of abrasion which might be termed erosive abrasion or abrasive erosion, as it is the double-sided counterpart of the single-sided solid erosion. Erosive abrasion accompanies any type of double-sided wear in which wear particles are detached from the surfaces, and thus is of very frequent occurrence; moreover, it will also occur if hard foreign particles, such as dust, find their way between the mating surfaces.

Adhesive wear is the type of double-sided wear *par excellence*, being characterized by an intense kind of interaction between the two mating surfaces, namely, by their mutual adhesion in the contact areas; the adhesion introduces stresses in the surface material in addition to those produced by the load. Notably the work by Bowden and his co-workers has shown that, even at normal temperatures, adhesion between two contacting solids can be so strong that junctions are formed locally, i.e., dispersed throughout that portion of the rubbing surfaces where they contact each other. If sliding takes place, shearing of these junctions can contribute substantially to the friction, unless a good boundary lubricant is employed. The consequent tearing of material can take place in different forms according to the relative strengths of the junction and of the two adjoining surface materials. Under mild conditions, wear rates need not be alarming; but at high loads and sliding speeds, especially when contact is of the concentrated type as in gears, the plucking out and possible transfer of particles from one surface to the other can easily result in the loss of self-control, i.e., in a self-aggravating type of wear.

In the foregoing, attention has been focused on types of wear representative of those where the mechanical aspects, in contradistinction to the chemical ones, play a major part. By way of example,

protective measures have been mentioned at random. Let us now treat them more systematically, i.e., by classifying them under three general principles of protection.

The relevant three general principles of combating wear are, firstly, the provision of protective layers; secondly, conversion, and, thirdly, diversion of wear attack.

The Principle of the Protective Layer.—This principle is widely applied also for combating corrosion (by anti-corrosive coatings) and weathering (by paint coatings). For single-sided types of wear, the protective layer may be exemplified by the Stellite shields on turbine blades (to protect them against the impingement of the water droplets present in wet steam) and by the rubber coatings meant to combat solid and cavitation erosion. In double-sided wear, the principle of the protective layer reduces to the very versatile method of contact inhibition, which amounts to ensuring the greatest possible degree of separation between the parent solids of the two mating surfaces.

Complete contact inhibition, in some cases, can be achieved by suitable design, such as the use of labyrinth instead of contact seals. Silentbloc bearings belong also to this category, which, however, is of restricted applicability. For instance, Silentbloc bearings, in view of the tolerable strain of the rubber layer interposed between the two mating surfaces, can be applied only if the stroke of the oscillating or reciprocating motion is relatively small. In other cases, it is the realization of full fluid-film, or, say, hydrodynamic lubrication that achieves complete contact-inhibition; the applicability of this expedient is limited, too.

Whenever some degree of contact cannot be avoided, partial contact-inhibition has to be resorted to. In characteristic cases, one then has to rely on protective surface layers in a solid or plastic state that are formed on either of the two mating surfaces prior to, or during, service. Even when the material of a surface layer is rather plastic, the layer may yet show a remarkable resistance to squeezing and wiping off under compressive, or tangential, forces, provided that it is thin enough; this is owing to the reinforcement through backing-up, by a comparatively strong substratum, of the parent material underneath the surface layer. Thus one can segregate the wear-resistant function of the surface from the bulk-structural function (bulk strength and rigidity) of the body underneath the surface.

With the base reactive metals commonly used in engineering, oxidation by the atmosphere produces natural oxide layers prior to service and these may increase wear resistance quite remarkably as compared with the naked parent metals. The formation of such layers, under suitable conditions, is accelerated by the rubbing action that takes place during service; it is then termed "frictional oxidation."

Protective layers can also be formed by an interaction between lubricant and rubbing surface; such layers are commonly termed "boundary layers." An early-recognized kind of interaction is physical adsorption. This results in the formation of boundary layers consisting of polar molecules adsorbed from the lubricant; the thickness of such layers appears to be of molecular dimensions. These layers offer a very limited protection, and even then only for as long as they remain solid (cf. the book by Bowden and Tabor, previously cited); in fact, they break down already at moderate temperatures. According to the extensive and revealing work by Bowden and his co-workers, the breakdown coincides with the melting point of the adsorbed substance.

Bowden and his co-workers have also shown that, if metal surfaces are suffi-

ciently chemically reactive, metal-soap layers are produced when fatty acids are present in the lubricant. The melting or softening point of the soap concerned being higher than that of the fatty acid, the protection against the adhesive wear to be combated extends toward higher temperatures, which, however, will not ordinarily exceed something like 150 deg. or 200 deg. C. Still higher temperatures are encountered in heavily-loaded rapidly-running gears; then the extreme-pressure lubricants have to be resorted to.

It seems that all of the above-discussed boundary layers have this in common, that they lose their protective action through melting or softening at some characteristic breakdown temperature. Further, a low yield strength of the layers in their solid state appears to be conducive to low friction between the rubbing surfaces. Especially when surface temperatures are substantially influenced by the frictional heat (in contradistinction to heat produced externally), a moderate breakdown temperature can be compensated somewhat by low friction. This conception has been applied by the author to the rating of extreme-pressure (E.P.) lubricants, or, say, of extreme-pressure layers, as to the protection they afford against scuffing; recently, Williams has systematically applied it to the classification and rating of boundary layers in general.

Finally, protective layers can be artificially applied prior to service. These layers, termed "coatings," are much thicker than boundary layers and their thickness is at least of the order of magnitude of one micron. Nowadays, they are available in a wide variety, especially in so far as they are formed by plating or by chemical means, i.e., by letting the rubbing surface in its initial unworn state react chemically with some suitable agent. Such surface treatments are very common in internal-combustion engines; carburising and nitriding are applied in gears, too.

The extensive class of chemical coatings may be exemplified by the coating produced by anodically oxidizing aluminum-alloy pistons; this coating is intended to reduce the scuffing risks during running-in, and, like many other coatings, has a limited life which need not exceed the running-in period. Prolonged life is obtainable with very thick coatings, such as are produced by the hard-facing (Stellite) of valve seats.

The Principle of Conversion.—Conversion of wear attack is the conversion of a destructive into a permissible type of wear. In judging the possibilities of a contemplated conversion, "limit analysis" can be very enlightening; limit analysis refers to the assessment of the limits, of the region of service conditions, that delimit each of the wear types concerned.

There are many examples where the principle of conversion combines with the principle of the protective layer. For instance, the chemical reactivity of extreme-pressure oils converts scuffing of gears or cutting tools into a mild and self-controlled kind of corrosive wear. The protective extreme-pressure boundary layer is continually being rubbed off, but simultaneously repaired, by the chemical reaction between the parent metal and the extreme-pressure additive in the oil; the continual reaction causes a gradual depletion of the additive, so that, in the end, the extreme-pressure oil becomes preceptibly less powerful.

An example where conversion of wear attack is effective by itself is provided by the choice of a cast iron which, in being rather vulnerable to abrasive wear, allows piston rings to wear-in rapidly. Indeed, on the whole, such scuffing risks can be diminished appreciably, despite the rapid wearing-in.

Another possibility for applying the principle of conversion lies in the redesign of machine parts. This may be

exemplified by the substitution of sliding by rolling bearings; then, if service lasts longer than pitting-fatigue life, pitting is substituted for ploughing and adhesive wear. An example of how wear can be converted into no wear at all is provided by the replacement of contact seals by labyrinth seals.

The Principle of Diversion.—Diversion is defined as diverting the wear attack from the surface that is economically more vulnerable to the other mating surface that can be replaced at less cost. This principle may be illustrated by the use of relatively soft and low-melting bearing materials in journal bearings; thus, in case of emergency, the punishment may be diverted from the journal to the bearing to a worthwhile extent. By its very nature, diversion can only be employed in cases of double-sided wear.

In retrospect, it is worthy of note that the basic reason for applying the above three principles lies in the problem of securing control of the type of wear obtaining or aimed at. In other words, these principles are useful in eliminating self-aggravation, the element of unwelcome surprise that characterizes the abnormality of critical types of wear; especially with such wear types, there is much need for supplementing their failing self-control.

It is thought that the three principles enunciated in the foregoing can guide the choice of materials for wearing parts (especially for their surfaces), the planning of maintenance, and, in cases of double-sided wear, also the choice of lubricants and lubricating methods (including the use of self-lubricating materials and of sealed rolling bearings, lubricated for life).

Apart from these general principles, there is a variety of empirical notions, rules, or formulae that mainly aim at condensing practical experience, but mostly have a limited applicability if they are not sheer illusion. One can, for instance, point to the limited applicability of the still widespread notion that a bearing metal should have a heterogeneous, e.g., a duplex, structure in that hard crystals, which are supposed to carry the load, are embedded in a soft matrix. The general truth of this rule is easily disproved by the example of the successful copper-lead bearing metals, in which it is reasonably certain that it is the soft lead inclusions that carry the load; further, certain homogeneous cadmium alloys perform quite well as bearing metals.

In the introductory section, it has already been concluded that increased effort needs to be devoted to waging war on wear. Workable knowledge about wear, despite the overwhelming amount of thought and energy bestowed on it, is still far from being as advanced as that about neighboring fields of structural strength and corrosion. This state of affairs is evidenced by the fact that there is as yet no single comprehensive book dealing with wear. In view of the steadily increasing economic importance of wear, this is disappointing, although it seems that the extension of knowledge at least keeps pace with the steady trend toward higher stresses and speeds of rubbing bodies and the consequent more intense frictional heating of their rubbing surfaces. Much could be achieved by disseminating, in unified form, the vast amount of practical and theoretical knowledge already gained in the diverse fields of wear; a logical subdivision of the matter, more or less along the lines indicated, would certainly lighten the task considerably.

Another indispensable means of mobilizing resources in the war on wear consists in marshaling research at an intensified rate; thanks to the available refined observational, measuring, and interpretative (e.g., statistical) techniques, the outlook for bridging the many gaps in our knowledge is much brighter than, say, one or two decades ago. The research should extend from one extreme, the highly fundamental

laboratory research, where the number of uncontrolled variables is kept to a minimum, to the other extreme, the statistical analysis of service performance with its many uncontrolled variables. The contradictions which too often exist, or appear to exist, between the results of the two extremes should be elucidated by intermediate stages of research, such as simulative bench-testing of isolated machine parts or of complete machinery.

Qualitative analysis of wear, comprising morphology and phenomenology, is well advanced nowadays. The same is not true of quantitative analysis, which aims at predicting wear rate under specified conditions of service. The latter analysis should be directed, more than has been done hitherto, toward investigating the interplay between the wear-resisting and the attacking factors; thus, badly needed insight could be gained into the important question of the extent of self-control of the different types of wear under different conditions. Last, but not least, "limit analysis," which represents a connecting link between qualitative and quantitative analysis, would yield the semi-quantitative information that is needed first of all in designing for wear, especially in so-called limit design.

DEVELOPMENT OF FIRE-RETARDANT DECK COVERING MATERIALS

E. A. BUKZIN, J. H. CHILCOTE, AND E. F. GREENLEAF

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DECK COVERING MATERIALS

Editor's Note

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Bare steel decks slowly are disappearing from modern ships of the United States Navy, particularly in interior spaces. The various materials now covering decks improve their appearance and attractiveness, and contribute to increased comfort of a ship's officers and men, with a long-recognized and measurable effect upon morale. However, this betterment of appearance and comfort is incidental to the foremost reason for deck coverings on naval vessels, which is safety. The increased use of these materials today stems not only from increased emphasis by Navy designers and planners upon such safety precautions, but also because new electronic gear and increased amounts of all equipment have both augmented and accentuated the hazards of electrical shock. This is especially true in areas about high-voltage apparatus, which now may utilize potentials as high as 20,000 volts.

One important form of present-day deck covering, therefore, is electrically insulating rubber matting, used aboard ship to protect personnel and equipment against accidental electrical contacts. For this purpose, substantial quantities of rigidly-tested rubber matting are being installed around electronic equipment, electrical switchboards, and everywhere men may be exposed to high voltage hazards. Such matting is required by specifications to insulate against direct discharge at 15,000 volts, and is tested for dielectric strength at a minimum potential of 40,000 volts. Since no one ever knows at exactly what spot a man might be standing when a short circuit or accidental contact occurs, the vital importance of every square inch of this matting being at least as good as minimum specification requirements is obvious.

In considering various materials for deck coverings, care must be observed that they do not contribute to increased fire hazard. Fire aboard ship can spell disaster to any vessel, but in naval craft the likelihood of fires obviously is greater than for merchant vessels, due to the hazards of combat or enemy action. World War II taught grim and costly lessons as to the importance of fire retardance aboard ship. However, fire resistance in deck covering was stressed as long ago as 1940, and even then "absolutely fireproof" materials were being sought in order to prevent the spreading of shipboard fires as well as to avoid the combustion of deck coverings in fires which resulted from explosions or enemy action. In describing general requirements of suitable deck covering, the Bureau of Ships told prospective manufacturers of many exacting needs. Resistance to shattering or splintering due to the shock of gunfire or explosion of shells or bombs was desired, in order to minimize additional damage to vessels or injury to personnel by flying fragments of deck covering. Where shipboard deck coverings are used for exterior spaces, they must be able to withstand exposure to sun, rain, snow, ice and sea water within a range of temperatures from 150°F to −20°F. This fantastic spread of conditions becomes more credible when it is realized that the same vessel which has been blistering under a blazing tropic sun shortly afterward may be battling its way against subzero gales whistling off the Arctic icepacks.

To perform satisfactorily as deck covering, a material must be sufficiently flexible not to be damaged by any expansion, contraction, or flexing of the deck. Furthermore, the material not only must be impervious to liquids which would corrode the deck or structure underneath, but neither may it contain ingredients which themselves would deteriorate the deck. The installed material must be relatively unaffected by contact with oil, gasoline, solvents or other liquids. Obviously, satisfactory deck coverings also must have excellent resistance to abrasion, cutting, gouging, tearing, and other wear or damage due to heavy foot traffic and the movement of stores or equipment. However, it also is essential that the material offer good non-slip characteristics, be sanitary, and yet offer no irritation even to personnel in bare feet. Weight of deck coverings, always a critical factor, must be kept to the lowest practicable limit. Although satisfactory covering materials may be fastened down by cements, the adhesion must be impervious to liquids, able to withstand flexing of the decks, unaffected by extreme temperatures, and at the same time not lessen the fire resistance of the installation.

In addition to this impressive array of "essential" requirements, numerous other characteristics should be sought in developing or considering any prospective deck covering. For example, it is desirable for the installed material to be neat, attractive, of pleasing color, free from unpleasant odors, and easy to clean, since appearance and comfort play a significant role in acceptability of a deck covering. The material should be easily repairable by the regular ship's crew in the shortest possible time, to avoid having to block off areas of the deck for long periods during repairs. It is also preferable that deck coverings, particularly for interior spaces, offer reasonably good heat insulation.

Although deeply aware of the desirability of obtaining incombustible deck coverings conforming to this impressive list of requirements, the Bureau met with only partial success during World War II in solving this problem. While materials such as light-weight coatings had been developed which were of limited combustibility, and useful on weather decks, these did not suffice for all of the widely differing applications in interior spaces. Consequently, the situation was reiterated briefly in 1946 by the Chief of Naval Operations in a message to all shipbuilding and repair activities, stating "The policy was established during the war of removing inflammable deck covering (linoleum) from ships in commission, and leaving decks bare in new construction. This policy was based on sound fire prevention reasons, and it remains in effect. The desire for deck covering as a comfort item is recognized for peacetime operations. However, inflammable deck covering will not be authorized." The Bureau of Ships was requested to continue its efforts to develop noninflammable deck covering materials.

A comprehensive review of the problem was undertaken to determine its basic characteristics, and the potential methods of approach to its solution. The Industrial Test Laboratory of the Philadelphia Naval Shipyard advanced a theory that the mechanism of propagation of shipboard fires by combustible materials generally followed a pattern of three basic steps:

(1) Vaporization of organic material, by heat transmitted through a bulkhead, producing very small blisters, which with additional heat, become large blisters.

(2) Rupture of the large blisters, with ignition of the gases evolved.

(3) Combustion of the blisters, resulting in propagation of flames through the material.

Since deck coverings may be laid over substantial areas, down corridors or along passageways, a combustible material, igniting in this manner, might easily and rapidly spread a fire which had been localized at the outset. Consequently, deck covering not only should be at least sufficiently slow burning not to contribute to the heat and intensity of a fire, but also should be sufficiently fire-retardant not to conduct flames away from their point of origin. Accordingly, in studying the fire-retardancy of a material, five critical factors should be considered:

(1) Ease of ignition

(2) Flame spread (the freedom and rapidity with which fire spreads over an ignited surface)

(3) Fuel contribution (the amount by which ignited material contributes to the intensity of a fire)

(4) Tendency to continue flaming after exposure

(5) Tendency to continue glowing after exposure

These five factors may determine the "fire penetration," or tendency of a fire to burn through an obstruction in its path. In addition to these actual combustion characteristics, it is also important to consider the amount of smoke generated by a material in burning, and the toxicity of any fumes created.

To develop deck coverings with improved fire retardance, there are several possible avenues of approach. For example, partial improvement would be attained if a material were developed which upon burning evolved non-combustible gases. This at least would not increase the intensity of a fire. Another possibility is to cover the combustible surface with a layer of non-combustible material, which would greatly reduce the amount of material available for burning. The most promising attack, short of developing entirely incombustible materials, appears to be the catalytic repression of combustion, resulting in formation of less volatile combustibles. The products offered today by industry as fire-retardant deck coverings are probably variations of this latter approach.

Since linoleum had been the most widely-used interior deck covering before the outbreak of World War II, it was natural that this material would receive the earliest concentrated efforts toward development in a fire-resistant composition. Several manufacturers engaged in a long cooperative program with the Philadelphia Naval Shipyard, the goal of which was to develop a linoleum that would be fire-resistant, would possess the desirable physical characteristics of standard linoleum, and would entail no radical changes in the existing manufacturing equipment used in large scale production. After many months of development and testing, materials which the manufacturers considered improved in fire resistance were submitted for evaluation, and numerous tests were conducted upon them at the Philadelphia Naval Shipyard. At the conclusion of the test program, it appeared that at least one satisfactory fire-retardant linoleum had been obtained. The Industrial Test Laboratory of the Philadelphia Naval Shipyard reported that the new linoleum, like any other material containing organic matter, could be ignited if continuously exposed to sufficiently high temperatures. However, in the laboratory tests, the fire-retardant linoleum not only did not sustain combustion, but the smoke which it emitted was not flammable, and thus did not contribute to enlargement of already existing fires. Where flaming or flashing was observed during tests of this material, they were of momentary duration, and at the limiting laboratory temperatures, the improved linoleum could not be further ignited to a point where it continued to burn after re-

moval of the source of ignition. In contrast, linoleum conforming to prewar standards could be ignited by exposure to considerably lower temperatures, was readily ignited to a point where it continued to burn with increasing vigor after removal of the sources of ignition, and emitted smoke which was in itself combustible. The Laboratory noted that although all samples of linoleum which were tested emitted smoke which was toxic upon extended exposure, much less smoke was evolved from the various experimental fire-retardant linoleums, and of these, the subsequently-approved material was the least objectionable.

Meanwhile, the search for deck covering materials with decreased combustibility had been broadened to include evaluation of many widely different types of material. In general, it seemed most practical to seek improved variations of those deck coverings which already had proven their worth in service. With this approach, measurement of the usual physical properties was routine, but the determination of the degree of combustibility of a material presented a problem, in view of the dearth of background information and recognized test methods. Since the laboratories engaged in this investigation had no adequate means of evaluating combustibility, the method of determining exactly what constituted "fire-retardance" in deck covering materials was evolved from a long program which included both laboratory and large-scale tests. The first step in this program of necessity was development of a satisfactory laboratory method of testing materials to measure their relative combustibility. One early technique the thermoelectric test, was developed at the Industrial Test Laboratory of the Philadelphia Naval Shipyard. In this procedure, an electrical current is short-circuited through a metal strip on which is mounted a 1″ × 8″ specimen of the material being evaluated. Combustion in this test is due to heat generated in the metal strip by the electric current, and not by exposure to open flame. This simulates the condition which might exist aboard ship where fire in one compartment will heat adjoining bulkheads, and materials fastened to these bulkheads may become ignited even though no open flame was present. This test technique is somewhat more severe than most other methods. Although improvements have been made, which permit better control and measurement of the temperatures created, and provide greater reproducibility, it has been difficult to correlate this test with performance.

A still earlier method, depending upon the presence of open flame, was developed by the Material Laboratory of the New York Naval Shipyard. Materials evaluated by this technique are mounted upon a steel panel and exposed to the direct flames of laboratory gas burners. Apparatus for this test is illustrated in Figure (1). Draft conditions in the communicating horizontal and vertical flues may be regulated, while fuel flow and other factors also may be carefully controlled. This method produces results more closely comparable to actual

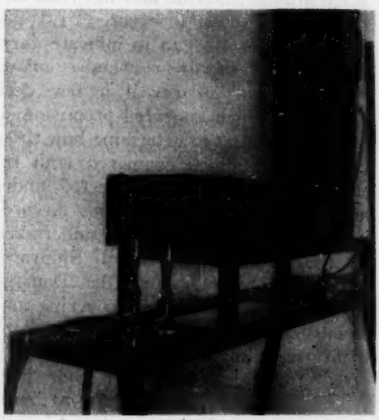


FIG. 1—Flammability Test Apparatus.

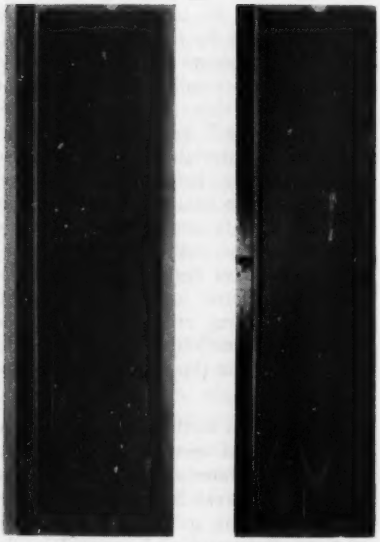


FIG. 2—Samples of Battleship Linoleum and Fire-Retardant Linoleum after Flammability Test.

shipboard fires, since the deck covering samples are subjected to direct flame as well as being laid upon a steel panel which becomes red hot. The results of tests by this method upon samples of conventional linoleum and fire-retardant linoleum are shown in Figure (2). When laboratory tests began to indicate varying degrees of fire-resistance among materials, and to reveal a few deck coverings which appeared promising, it became essential to determine how these laboratory findings compared with results which might be expected under actual or full-scale conditions. Accordingly, a series of tests was undertaken at the Philadelphia Naval Shipyard, with the cooperation of the Damage Control Center. The deck covering materials which appeared most resistant to fire were compared with other materials offering moderate or poor fire-retardance. For this program, a three-deck structure which represented in full scale a typical section of a naval vessel was used. Samples of about fifty square yards each of deck covering were mounted on steel plates and installed in the lower two decks of the structure. A pan of fuel oil was ignited in the structure under controlled conditions carefully chosen to correspond to the approximate intensity and heat of an actual shipboard fire. Time and intensity of the fires, temperatures, and degree of propagation of the fire were observed.

This program of full-scale tests generally confirmed the preliminary classifications placed upon the deck coverings as a result of laboratory tests. For example, fire-retardant linoleum samples conforming with the new specification offered remarkable resistance to the fires, and did not contribute to the conflagration, although conventional linoleum and plastic tiles burned vigorously and were badly damaged.

Even more convincing were the observations of tests of rubber matting, in which samples of a fire-retardant compound were compared with standard matting selected from Navy stock. The standard matting was completely consumed in the lower deck of the structure, where the oil fire had been set. Furthermore, this matting caught fire spontaneously on the upper deck, although exposed to no direct flame, and burned severely. In contrast, the new fire-retardant matting burned on the lower deck only where exposed to the hottest flames of the oil fire, and showed little or no tendency to propagate the fire, while on the upper deck this improved compound did not burn and exhibited only a small amount of blistering in those areas subjected to the most intense heat.

These full-scale tests presented the Navy with gratifying and convincing support of its laboratory findings. With this clear proof of the practicality and

validity of the standards which had been proposed as a result of laboratory evaluations, it was possible to establish sound specification limits for fire resistance. Furthermore, since all materials tested in the full-scale tests either had been drawn from Navy standard stock or had been contributed by industrial manufacturers, all these samples represented deck coverings which were commercially feasible, and available in quantity.

As a result of this long development and evaluation program carried out cooperatively by industry, the Bureau of Ships, and its laboratories, there is now available to the Navy a choice of several different fire-retardant deck coverings. Other agencies, notably the Maritime Administration, have expressed interest in using these materials; and even commercial shipbuilders are said to be using fire-retardant deck coverings in some of the newest passenger liners. It appears, therefore, that the initial problem of discovering or developing materials which were fire-retardant and which also possessed the other desirable characteristics of deck coverings has been successfully answered. The engineers or technical personnel of the Navy who determine which types of deck covering shall be used, and where decks shall be covered, now have a choice of several materials from which to select.

For general-purpose deck covering applications, fire-retardant linoleum, described by specification MIL-L-2904, now is used in considerable quantity aboard naval vessels, especially in living quarters. This improved product looks like ordinary linoleum, and possesses many of its same physical characteristics, but has markedly improved wearing qualities.

Where electrical protection is required, as around electrical switchboards or electronic equipment, insulating rubber matting especially compounded for fire retardance is widely used in ever-increasing quantities. Synthetic rubber matting for this use is described by specification MIL-M-15562. Long-regarded as almost an impossibility, the development of fire-retardant deck covering from synthetic rubber is a major accomplishment in technical compounding of which industry well may be proud. Recently this matting also has become available in colors such as gray or green, which contribute to a more attractive appearance than the conventional black. Possibly light-colored fire-retardant rubber matting also will be considered for applications in interior spaces aboard ship where electrical protection is not needed. For this use $\frac{1}{8}$" thicknesses in place of the present $\frac{1}{4}$" thick material are probable.

Light weight deck coverings were developed early in World War II which proved suitable for exterior use such as the weather decks of naval vessels. By several different means, these deck coverings applied a non-slip surface of abrasive particles in a thin layer over the deck areas. One type of product, now described by specification MIL-D-2905, was comprised of an abrasive-coated fabric which could be cemented to the steel deck. A slightly different material is covered by specification MIL-D-15170, which describes a deck coating consisting of abrasive and synthetic binder, capable of being applied as a coating, by spraying, brushing, or troweling. More recently, a fabric coated with plastic particles has been developed which can be attached to the deck by a pressure-sensitive adhesive and which is now covered by specification MIL-D-16651. All of these light-weight, non-slip deck covering materials are fire-resistant, long-wearing, and able to withstand the effects of sunlight, weathering, and salt water. Although intended primarily for weather decks, these materials have been used successfully in passageways and as treads on steps.

In a number of interior spaces aboard ship, decks are likely to be wet or may have oil or grease spilled upon them. Such areas as shower stalls, washrooms, and heads for example, present constant slipping hazards, while galleys not only become slippery but prove difficult to keep clean and sanitary without suitable deck covering. Light-weight rubber matting is seeing service already in a few experimental installations in shower stalls and wash rooms. However, for other wet space and galley installations, latex mastic deck covering complying with specification MIL-D-3134 or magnesium oxychloride cement material described by specification MIL-D-16680 is available for use. The latex mastic deck covering which looks like concrete, is made from a mixture of synthetic rubber latex, Portland cement, and marble chips. The material can be troweled onto a deck, hardens fairly rapidly, and may be repaired by ships' crews. This attractive, long-wearing deck covering offers good resistance to slipping, is easy to clean and keep sanitary, resists oils, greases, and salt water corrosion, and is virtually incombustible by specification tests. The magnesium oxychloride cement (known in industry as "magnesite") is made by mixing a magnesium chloride solution and a dry mix consisting of magnesia with fillers such as silica, talc, expanded vermiculite, or marble chips. The magnesia reacts with the magnesium chloride to form a magnesium oxychloride cement which sets in a few hours to form a hard stone-like deck covering that is attractive as well as long wearing.

In addition to electrical protection, reduction of slipping hazards, and wet space usage, deck covering is sometimes needed for vibration absorption. Where personnel are required to stand for prolonged periods with little freedom to move about, as for example, men on watch or on the bridge, it has been found that protection from con-

FIG. 3—Synthetic Rubber Standing Mat.

tinuous vibration underfoot provides substantial reductions in fatigue, with important improvement in efficiency. For this purpose, a series of experiments led to development of a synthetic rubber standing mat which can be installed at locations where needed, and which substantially reduces vibration transmitted through the feet. The design of a synthetic rubber mat which afforded the desired vibration absorption, and at the same time, remained fire-retardant, easy to clean, skid-resistant, light-weight, and long-wearing, has been a difficult task which entailed design and development by industry, preliminary testing by Navy Laboratories, and careful service testing aboard ship. Two experimental standing mats are shown in Figures (3) and (4), while Figure (5) illustrates the surface design now considered most suitable.

Several entirely new types of materials have been developed recently for possible use as deck coverings. Classified as "roll goods," two of the most promising of these have shown rather good fire-resistance, and are very light in weight. One material is composed of abrasive grit embedded in a plastic film which is bonded to a fire-resistant fabric or paper composition backing, while the other potentially interesting product is an organosol fused at high temperature onto fibreglas. Both of these deck coverings appear to offer excellent resistance to wear, oils, greases, salt water, and light, as well as being neat, easy to clean, readily applied, and easy to repair. For living spaces such as mess rooms and quarters, these materials may find considerable application.

At present, therefore, the Navy is fortunate in having available a considerable variety of fire-retardant deck covering materials from which the product most suited to a particular need may be chosen. Most of these deck coverings are now described by formal specifications, and all of these specifications in turn describe materials which have been shown to be commercially available in

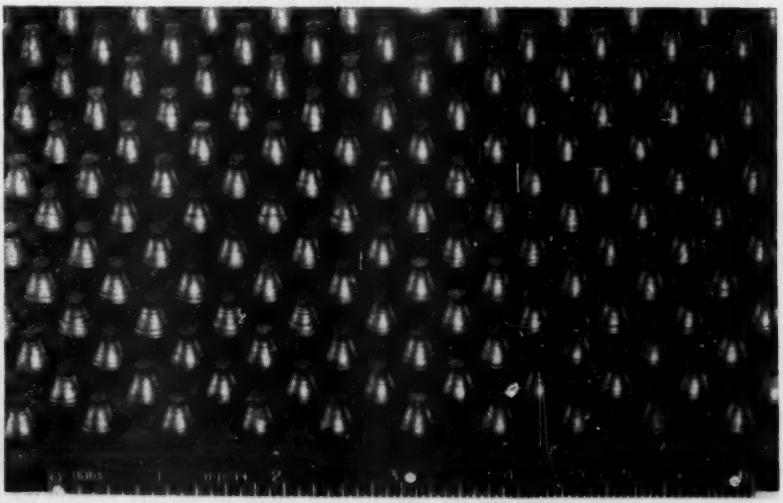


FIG. 4—Synthetic Rubber Standing Mat.

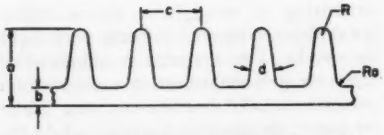


FIG. 5—Cross-Section of Synthetic Rubber Ribbed Standing Mats.

a—5/8 inch	d—15 degrees
b—1/8 inch	R—1/16 inch
c—1/2 inch	Ra—1/16 inch

reasonable quantities. The rigid requirements for fire resistance which the Navy demands of its shipboard deck coverings have been demonstrated by actual full-scale tests to be practical, both as to the nature of the specification tests and the limits established.

While we cannot hope to prevent every conflagration from breaking out aboard ship, any step which limits the extent of the damage from fires is worth while, from the viewpoint of human lives saved and injuries spared, as well as the very considerable economic and strategic benefits of preventing damage to naval vessels. The long painstaking cooperative program to develop fire-retardant deck coverings represents a practical solution to a vital problem. Navy laboratories succeeded in defining the scope and limits of this need, as well as devising ways of measuring the suitability of potential deck coverings, but the contribution by industry of technical knowledge, production skill, and all of the expense of developing suitable materials was a major factor in solving this problem. The development of fire-retardant deck covering for shipboard use is indeed an accomplishment in which all personnel concerned may well take pride.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the Bureau of Ships, Department of the Navy, for permission to publish the information contained in this paper. Full acknowledgment should be accorded to the personnel of the Material Laboratory of the New York Naval Shipyard and of the Industrial Test Laboratory and the Damage Control Center at Philadelphia Naval Shipyard, whose careful and painstaking test work provided the basis for much of this article. In addition, the contributions and advice of Messrs. Leon Birnbaum and I. D. Gessow of the Bureau of Ships have aided greatly in improving the accuracy and completeness of this presentation. The authors particularly wish to acknowledge the encouragement provided by Mr. T. A. Werkenthin, Head, Elastomer Branch, Bureau of Ships, whose leadership inspired the preparation of this article.

ADDED KICK FOR TURBOJET ENGINES

ACKNOWLEDGMENT

This article was published in the July 1952 issue of "General Electric Review." Its authors are G. W. LAWSON and W. C. ALEXANDER of General Electric's Aircraft Gas Turbine Division, River Works, West Lynn, Mass. The article discusses the additional thrust obtained by means of an injection of a water and alcohol mixture.

Getting an 80-ton airplane into the air in a matter of seconds is no easy job. The problem is one of providing more than normal maximum thrust or "kick" at take-off. In the case of B-45 and B-47 jet bombers, their power plants (J-47 turbojet engines—one is shown on the next page) were equipped with combustion-chamber water-alcohol injection systems for augmenting thrust.

Variations of these systems boost the take-off thrust from 15 to 25 percent or higher. As a result, heavy jet-powered aircraft can take off from minimum-length runways with maximum safety.

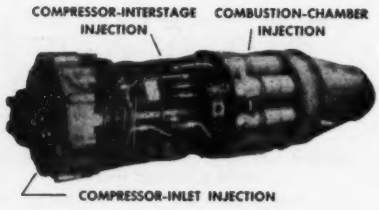
WHAT IT DOES

The use of water injection in aircraft power plants isn't new; its use to increase power output in reciprocating aircraft engines has been common for many years. Power output in this type of engine is limited by detonation, preignition, and decreased density of charge because of high inlet-air temperatures. To offset this limitation a water-and-alcohol mixture is injected as a *coolant.*

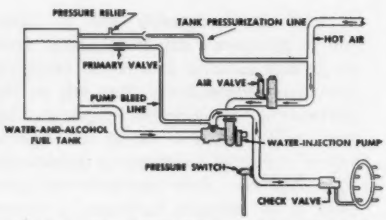
On the other hand, the use of water-alcohol injection in the turbojet engine not only is new, but also its purpose is quite different. Here there are no preignition or detonation difficulties to contend with.

An indirect purpose of water injection is to decrease compressor inlet temperature. The main purpose, however, is to increase the *mass flow* through the turbine and to increase the *pressure ratio* (discharge pressure divided by inlet pressure). Output or thrust of the cycle is thereby increased. An equation for the gross thrust, showing how the increase comes about, is at the end of this article.

The detailed process whereby 60 gallons of water a minute is forced into the *combustion* system without extinguishing the flame is an interesting problem. It's one of the many that required solution during development of the turbojet liquid-injection system. In fact, various developments over a two-year period raised the efficient liquid-



VARIATIONS OF INJECTION SYSTEMS BOOST TAKE-OFF THRUST 15 TO 25 PERCENT



LIQUID INJECTION INTO COMBUSTION BURNER BEGAN WITH THE LOW-FLOW SYSTEM

injection limit to a rate of over 125 gallons per minute.

It's true that the effect of introducing a liquid into the combustion zone is harmful to combustion efficiency. But the increased gas flow and higher compressor-pressure ratio results in a larger amount of energy available in the gases leaving the burner. What you might call a secondary but nonetheless significant effect also occurs—this is a further increase in output because of the higher specific heat of the liquid-and-gas mixture.

Liquid injection in turbojet engines isn't limited to combustion systems. Important gains are also realized in reducing the work of compression by cooling the air before it enters the compressor or during the compression cycle. Because of their high latent heats of vaporization, water or water-alcohol mixtures are ideal fluids.

COMBUSTION INJECTION

All the water injected into a combustion burner must be evaporated within the burner for best results. This process is analogous to that of a flash boiler. That is, additional fuel is required to evaporate the water and heat it to the burner-exit temperature. This additional fuel is supplied by adding alcohol (or some other combustible fluid) to the water.

Development of the combustion-injection method started with a *low-flow* system that was installed in standard combustion chambers. To effectively operate the water system, a pump and control system was developed, shown schematically above. It consists of an air-driven centrifugal water pump, water valving, and air valves. The pressurized tank and priming valve insures that the pump-inlet cavity is always full. If the pressure drops below a certain limit, a pressure switch located at the pump discharge closes the solenoid air valve immediately. This rapid action is necessary to prevent the unloaded pump from overspeeding when the tank is emptied. The check valve prevents the flow of hot gas from the engine to the pump during the "off" period.

COMPRESSOR INJECTION

In practice, a water-and-alcohol mixture is sprayed into the air intake ahead of the compressor. The compressor then takes over and the mixture passes through a series of nozzles (stationary blades) between stages.

Several conditions determine the amount of water that will be evaporated

ahead of the compressor. They are: fineness of spray; temperature and relative humidity of the air; quantity of the liquid, and the time required for mixing. Evaporation at this point causes a decrease in the temperature of the inlet air. The lower temperature increases the density of this incoming air with a resultant increase in the mass flow of air through the engine. Increase in mass air flow results in an increase in compressor-pressure ratio, to produce an over-all rise in the total thrust of the cycle. This is accomplished without increasing the work of compression or delivery per unit mass of the air.

WHICH METHOD?

From the efficiency point of view, compressor injection appears more desirable. Yet this method imposes several serious operational disadvantages. For instance, demineralized water is sometimes necessary to prevent performance losses. These losses result from calcium-bearing minerals in the water that are deposited on the compressor and turbine blades. Also, if compressor air is bled off for cabin-air supercharging or for wing deicing, undesirable water and moisture finds its way into the cockpit and cabin and various other components. And, of course, water freezes in cold weather and at high altitudes. True, alcohol added to the water may prevent freezing. But if compressor air passes through the cabin during thrust-augmenting periods, its use is obviously out of the question.

Another serious problem of a mechanical nature limits the quantity of liquid that can be injected into the compressor. This limitation is imposed because the contraction of the relatively thin stator casing is greater than that of the rotor with its heavier mass. The result is that the rotor blades rub on the stator casing at higher liquid flows. The blade clearance can be increased to allow for this differential contraction during the injection, or cooling, process. But then decreased performance during the nonaugmented, or dry, period must be considered.

The combustion-injection method isn't as attractive from the percent-augmentation versus water-rate point of view. However, it does not have the disadvantages currently associated with the compressor method. Not that the combustion method is without its problems. The difference is that at the present state of development they are more readily solved. It's because of this that successful progress has been made with the combustion method.

IMPROVEMENT PROGRESS

Attempts to completely vaporize larger quantities of water-and-alcohol mixtures within the combustion chambers take various forms.

A discovery made during the analysis and development of different systems indicated that changes in the basic design of the combustion chamber had big effects on water-injection performance. The water-injection program, therefore, was run in parallel with a combustion-chamber improvement program. The dual program has fostered many changes in design of the combustion chamber and in the water system.

Several different nozzle configurations were tried. Some showed promise but didn't give enough improvement to justify their incorporation. A *high-flow* configuration that more than doubled the amount of water and alcohol that could be vaporized in the combustion chamber was finally developed. This, of course, resulted in correspondingly higher thrust augmentation.

Simultaneously with these, another

program saw improvement on the accessories and controls for the water-and-alcohol system. The turbine-driven pump was redesigned to give the higher flow and discharge pressure required by the new high-flow system. Faults in the original pump, such as susceptibility to corrosive attack by the water-and-alcohol mixture, were corrected in the new design. Similarly, other control components of the system, shown in the schematic diagram, were redesigned for better results.

The improved control system has gone through several hundred hours of performance and endurance tests under simulated field conditions. They were trouble-free hours and proved the reliability of the improved system.

The equation for the gross thrust per cycle is

$$F_g = \frac{W}{g}\left[K\sqrt{T_n}\sqrt{1-\left(\frac{P_a}{P_n}\right)^{\frac{\delta-1}{\delta}}} - V_a \right]$$

where

F_g = gross thrust per cycle
T_n = total temperature at jet nozzle
P_n = total pressure at jet nozzle
P_a = ambient static pressure
V_a = airplane velocity
δ = ratio of specific heat of mixture
W = mass flow of mixture

EVAPORATOR CLEANING BY SHIP'S PERSONNEL

ENSIGN EVERETT C. HUNT, USNR, AND
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THE AUTHORS

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Several years ago, while serving as a cadet on a merchant vessel, one of the authors had an opportunity to observe a costly error in evaporator cleaning by ship's personnel. The evaporator was of the single shell comparatively high pressure type common to merchant ships. A strong acid solution (about 6 normal) was circulated through the pumps, distiller condenser and shell for about five hours. Obviously the shell was cleaned, but the distiller condenser was so badly damaged that it had to be completely retubed. This was a sad experience, but with proper instruction shipboard personnel can safely and effectively clean evaporators.

Evaporators are employed on shipboard to convert sea water into fresh water for boiler feed and potable water uses. To accomplish this the brine is heated under vacuum to above the boiling point in the evaporator shell and the vapor is condensed in the distiller condenser as fresh water. The salt in the brine remains behind in the evaporator shell and is discharged as a concentrated brine. The concentration is sufficient to cause some of the salts to precipitate on the hot evaporator tube nest, shell, and brine line forming a thick scale. The salts contained in ocean brine are many and varied, but can largely be considered and treated as carbonates of the alkaline earth metals, $CaCO_3$ and $MgCO_3$. These carbonates form a hard low heat conductant scale on the heat exchanger surfaces and pipes of the evaporator reducing the efficiency and capacity of the unit. It is, therefore very desirable to remove these deposits.

Hydrochloric acid will react with calcium and magnesium carbonates forming water soluble Ca and Mg chlorides, water and CO_2 gas by the following reactions:

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2 \uparrow$$

$$MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2 \uparrow$$

These reactions are, in any practical consideration, irreversible because of the minute solubility of CO_2 in water or HCl solution at the temperature (130°-170°F.) used in cleaning and the low dissociation of H_2O.

Some years ago, at the Boston Naval Shipyard, extensive laboratory research was conducted by Capt. Nichols and Mr. Rozene, proving that a 1% solution (0.275N) of HCl would be harmless to the metal parts of the evaporator which are of admiralty brass and copper-nickel.

Employing this information, these gentlemen developed the Nichols-Rozene Acid Cleaning method which was used by the authors to clean the 20,000 gallon per day, Foster-Wheeler, double effect, two shell evaporator units after six months of service.

The general procedure for circulating the acid solution in any evaporator unit is as follows; a connection must be made from the discharge side of the brine overboard pump to the discharge side of the circulating pump; a 50-gallon drum, which is to serve as the acid reservoir, must be placed high enough on an upper deck to provide sufficient head and be connected to the suction side of the brine overboard pump. Rubber hose will serve well for both purposes, and the thermometer wells may prove an excellent point at which to connect into the lines. Valves must be located in both lines. All valves in the circulating water and feed water systems must be opened except the brine overboard valve. When the brine overboard pump is operated the acid solution will circulate through the condensate cooler shell, the distiller condenser shell, air ejector condenser shell, evaporator feed pump, the vapor heater or heaters, the first effect shell, second effect shell, etc., and return to the brine overboard pump to be recirculated. The evaporator air ejector must be operated to free the shell of gasses produced during the reaction. Four to six inches (Hg) vacuum must be maintained.

The acid solution is prepared in the 50-gallon drum by mixing 10 gallon acid with 40 gallon of fresh water. Because a more than 1% acid solution or .275N might prove harmful to the pump, the drum discharge valve should be adjusted to allow about 10 minutes for the solution to enter the system. Before the acid is run down to the pump, enough fresh water must be placed in the shells to establish circulation and to have a third of a gage glass of water visible in each shell.

The capacity of the unit is about 900 gallons. Since over 50 gallons of 5N acid would be required to raise this quantity of water to the strength recommended for cleaning (.25N), a procedure to conserve acid was desirable. It was found that the total amount of water needed could be reduced if the solution flow from the first effect to the second effect was throttled allowing the first effect shell level to rise sufficiently to cover the entire tube nest bundle and thus accomplish the cleaning in the first effect shell. To raise the level in the second effect shell, the brine feed valve to the second effect was opened fully while the suction from the shell was throttled. The vacuum was then increased several inches (Hg) causing the second effect shell solution level to rise high enough to cover the tube nest. By changing the level of the solution in the two shells, it was possible to avoid the use of from 200 to 300 gallons of water which resulted in the saving of from 15 to 20 gallons of 5N acid.

As mentioned before a solution greater than 1% or .275N may prove harmful

to the metallic surfaces. It is therefore, desirable to maintain a close control of the normality of the circulating solution. To do this titrations should be made about every fifteen minutes with a standard solution, (.5N NaOH). The record of these titrations will indicate the progress of the reaction, showing the rate of acid consumption, the normality of the solution, and the completion of the cleaning process. The latter will be indicated by a series of constant normality readings, when acid is not being added. To protect the metal and yet provide adequate cleaning effect, the solution strength is limited to a normality range of .2N to .3N, 4ml to 6ml of standard titrating solution per 10ml of sample circulating solution.

When the reaction is completed, as indicated by the titrations, the unit must be flushed out by opening the brine overboard valve. The shells must then be filled with fresh water while an alkaline solution is run down from the drum. The flushing must be continued until the surfaces appear clean and the titrations indicate that the metal surfaces have become neutralized.

Estimating the amount of acid required to accomplish the cleaning of a particular evaporator unit is a difficult task and only experience can dictate the amount necessary. The variables involved in estimating the required acid are the capacity of the unit, hours in operation before cleaning, quantity of solution necessary to fill pipe lines, condensers and shell, the effectiveness of the cold shocking while the unit is in use and the normality of the acid available. About 800 lbs. of 5N acid was required to clean each unit on the CVE-58 after 6 months of operation.

To insure safety to personnel and property a person familiar with the handling of concentrated acids should be selected to supervise the cleaning. The personnel must be instructed in detail concerning the handling, the danger of smoking, where the acid is being poured, and the procedure to be followed in event of spilling acid on themselves or the deck. They must be equipped with goggles, rubber gloves, and be completely covered. Foul weather gear is excellent for the latter. Perhaps the safest method of mixing the acid is the use of an eductor on the water line to the drum so that the acid is drawn from the bottles and mixed in the hose while running into the drum. However, eductors are not usually readily available and it is necessary to manually pour the acid. This can be done safely if the foregoing instructions are followed.

The results of this cleaning method when used were excellent. The metal surfaces appeared clean and metallic when inspected. The cleaning time was about eight hours. This is certainly far superior to the less effective, time-consuming and laborious task of opening the units and scraping the scale away.

APPENDIX

Titration results showing fluctuations of normality as the acid is added and used up. Note the series of constant readings indicating cleaning is completed. (Readings indicated by *.)

Time	*Norm.*	*Mls. Base*	*Time*	*Norm.*	*Mls. Base*
1415	0.080	1.6	1530	0.015	0.3
1430	0.065	1.3	1545	0.020	0.4
1445	0.045	0.9	1600	0.024	0.4
1500	0.035	0.7	1615	0.100	2.0
1515	0.025	0.5	1630	0.060	1.2

Time	*Norm.*	*Mls. Base*	*Time*	*Norm.*	*Mls. Base*
1645	0.200	4.0	2045	0.175	3.5
1700	0.110	2.2	2100	0.165	3.3
1715	0.075	1.5	2115	0.156	3.3
1730	0.250	5.0	2130	0.155	3.3
1745	0.125	2.5	2145*	0.285	5.7
1800	0.105	2.1	2200*	0.280	5.6
1815	0.175	3.5	2215*	0.285	5.7
1830	0.115	2.3	2230*	0.280	5.6
1845	0.105	2.1	2245*	0.285	5.7
1900	0.125	2.5	2300*	0.280	5.6
1915	0.150	3.0	2330	0.015	0.3 (1st flush) 1¼# B.C.
1930	0.140	2.8			
1945	0.135	2.7	2345	0.015	0.3 (2nd flush) 1¼# B.C.
2000	0.150	3.0			
2015	0.165	3.3	2400	0.007	0.15 (3rd flush) 1¼# B.C.
2030	0.170	3.4			

THE AIR-CONDITIONED COMBAT SHIP

A Mid-Twentieth Century Engineering Necessity.

COMMANDER GEORGE C. WELLS, USN

THE AUTHOR

graduated from the U.S. Naval Academy in 1934. He received postgraduate instruction in Naval Architecture at the Massachusetts Institute of Technology from 1936-1939. In the period January 1946-July 1949 he was head of the Air Conditioning Branch of the Bureau of Ships. In this period the systems for the first fully air-conditioned surface combat vessels were designed, installed and the ships received their early service tests. He is currently assigned to duty as the Industrial Engineering Officer, Boston Naval Shipyard.

In the past ten years there has been an apparently steady trend toward the provision of air conditioned living, berthing, and fighting spaces on combat ships.

In the minds of many people, this trend is in response to the demand of the American citizen for maximum available creature comfort—a provision of luxury really unnecessary. After all, we did successfully operate combat ships for many years with only casual installations even of forced ventilation. As the amount of heat producing equipment installed in other than machinery spaces increased, we used fans to pump weather air through the ship and continued to operate our ships in a most effective manner. But steadily growing quantities of equipment installed on our ships has meant larger and larger crews and less and less freedom of selection as to where to provide hotel spaces—living spaces—for the crews. Those who would belittle the demand of the American for comfortable living would do well to remember that there is a considerable difference between the problem of providing reasonably habitable spaces contiguous to the shell, at or above the waterline, and the one of offering livable spaces often under armor and sitting directly on top of machinery spaces which generate propulsive effort often in excess of 100,000 horsepower.

There are those who recognize that it is substantially impossible to provide decent living conditions in a hull crowded with machinery unless air conditioning is used to some extent. These

individuals have pioneered the provision of air conditioning as a shipboard function. The premise has been taken that minimum air conditioning should be provided which will prevent deterioration of the health and effectiveness of the crew. It has been found that man, who is the heart of the ship, can withstand intermittent exposure to almost unbelievable conditions of daily work and of fighting the ship provided he can be furnished a modicum of comfort during his periods of rest. Some idea of what conditions of environmental air man can endure will be discussed later.

Those who recognized the real need for limited air conditioning must receive the fullest commendation for their work in determination of minimum requirements for the use of air conditioning; and for the extent to which the air conditioned combat ship is, today, accepted as a necessity. Unfortunately, however, there has grown the idea that the ship is conditioned at the expense of space consumption, weight addition, and of engineering design and maintenance complexities.

The thesis is here taken that it is necessary to condition a modern combat vessel of tonnage, horsepower, and equipment complexity encountered in destroyers and larger sizes. This necessity stems not primarily from the requirement that decent conditions of habitability be furnished but from the need to offer the simplest, lightest, and most compact ship possible. It is submitted that it is an engineering impossibility to counteract the heat gains on these ships by the use of weather air pumped in and out of the ship.

Let us consider some of the things that are known about environmental air temperatures that can be withstood for intermittent work and air temperatures at which man is comfortable. Possibly the human being is not directly conscious of being in a comfortable air environment. He is acutely conscious of discomfort, however, particularly when not at work and when trying to relax. Lightly clothed and at rest, or doing desk work, the greatest number of people are least conscious of discomfort—hence most comfortable—when the air has an effective temperature (ET) of about 70°F. Effective temperature is a combination of air movement, air dry bulb temperature, and air relative humidity which serves as an index of the degree of warmth experienced by the human body. With little air movement a 70° ET exists when dry bulb temperatures vary from 73° to 77° F. and relative humidities correspondingly vary from 70 percent to 40 percent.

Continuously exposed to an ET of 85° all people will develop heat rash that is sufficient to interfere with sleep. Continuously exposed to an ET of 76° to 78°—the threshold of sensible perspiration for people at rest—men will stay free of rash and can sleep in comparative comfort. They will, generally, remain in good health and be able to work effectively if required intermittently to work in areas having much higher temperatures provided they can spend periods of rest, including sleep, in spaces having this ET maintained. Given intermittent exposures not exceeding four hours normally healthy individuals can perform light work in temperatures up to 115° F, and even higher temperatures can be withstood provided there are oases of blast cooling in which the men may spend most of their working time. To recapitulate—a man is quite comfortable at 70° E.T. He can rest well in environmental atmospheres having temperatures in the order of 76° E.T. to 78° E.T. He will suffer from heat rash if continuously exposed to temperatures of 85° E.T. He can perform work in atmospheres having much higher temperatures than these provided exposures are intermittent in nature.

Rarely is the combat ship built for operation restricted to a small part of

the world's oceans. The climate in all seas of the world and in all seasons of the year must be duly considered when weather temperatures to be used in basic design are chosen. A summer dry bulb temperature of 88° to 90° F. with a relative humidity at that temperature of 70 percent must be expected to be often encountered. There are areas, notably the Persian Gulf, where higher temperatures are found but an assumption of a summer design condition of 88° F. dry bulb and 70 percent relative humidity would seem to be a reasonable one.

This condition of air is already one of higher heat content than that of air in which we can live continuously at rest, without sensible perspiration; and it is on the threshold of being that environmental atmosphere in which all hands may be expected to develop heat rash. Discouraging indeed are the prospects of use of this air to remove heat from a ship and at the same time provide something approaching a habitable ship.

Air is a very poor medium for the removal of waste heat from equipment. It is light, weighing only about 0.075 pounds per cubic foot at standard atmospheric conditions. It has a very low specific heat—about 0.24 BTU/lb/°F. For the same allowable temperature rise of the cooling medium one gallon of water will accomplish the same heat removal as about 3100 gallons of air!

On the face of it one would seem to be stupid to use air as an equipment cooling medium. Unfortunately though, the human cannot exist in an environment of water. Further, much equipment must be installed in areas remote from available cooling water. Further, provided air can conceivably be used as the cooling medium, it can be used more easily than more effective liquids. After all, it is right there in the compartment, it must be there for habitation. It can be pumped from the compartment through the equipment and *back to the compartment* with comparative ease. Usually, the engineer who designs the equipment to be cooled by air has little incentive to design for the use of any other cooling than the air in the space in which the equipment is installed. There seems to be no probability that there will be any sizable shift from air to other media for the cooling of much of the heat producing equipment installed on combat ships.

The day of the living and berthing space located above the water line, bounded on one or both sides by the skin of the ship, and communicating freely with the weather through the medium of port holes—or at most short runs of ventilation duct work, is now so far past as never to have been witnessed by any but Navy personnel who have been in service since before the beginning of World War II. Spaces once assignable to berthing must now be used for complex equipment or for administration of the larger crews needed to man the equipment.

Today we are limited both by the number of spaces assignable to berthing and messing and by the possible location in the ship of those spaces. So today we find spaces assigned to hotel purposes which contain heat producing equipment, which must accommodate many men, and which often are contiguous to truly major heat producing spaces—boiler rooms and main propulsion engine rooms.

The problem of providing suitable weather air intakes becomes increasingly difficult with every new ship design. Ideally, the intake is located in a high dry spot on the ship, on the center line, spaced fore and aft equidistant from watertight bulkheads bounding the compartment or compartments served by the system; free of the possibility of drawing into the ship heated air which has just been exhausted from the ship, and free of any pocketing and pre-heating

effects of adjacent structure. The intake should be readily capable of closure so that, if desired, a completely tight ship envelope can be realized.

Of course it has never been possible to meet all criteria for ideal location of all weather air intakes. But each of these requirements has become increasingly difficult to satisfy.

The high dry spot is hard to find. By the nature of things, the high dry spot is also the proper location for secondary battery guns and for fire control and ship control equipment. Since we are building combat vessels it is only common sense that the weapons which give the ship part of her offensive strength shall be placed in these locations. On all ships the number of weapons and fire control equipment has steadily increased, on some it seems, astronomically.

The superstructure area appears at first glance to be the optimum place for weather air intake openings, and in fact many are located there. But the volume of superstructure available for duct runs decreases as the demand for additional administrative and operating spaces grows more pronounced. The increasing demand for these spaces has been noted.

The transverse compartmentation of the fighting ship has become most extensive. This is necessary to insure a reasonable chance of ship survival when successfully attacked. But this compartmentation has practically eliminated the possibility of locating weather air intakes centrally over each transverse watertight subdivision. Consequently, the ventilation system often, indeed usually, must have long and tortuous duct runs from the weather to the point of air delivery. Further, since watertight bulkheads are pierced there must be heavy closures with associated operating gear placed at the bulkheads.

As if this were not enough, another obstacle to ideal location of intakes now makes itself felt. If air is to be moved, a static pressure differential must exist. When this differential exists it becomes quite a chore to open and close doors within the watertight subdivision served by the ventilation system. To minimize the extent of static pressure differential between compartments, and to insure as well-controlled volume of air flow as possible, it is necessary to install mechanical exhaust systems substantially of the same capacity as of the supply system, so there are not one, but two ventilation weather openings to most compartments. And these openings must be so located that there is no air recirculation between them, else we shall be attempting to cool the ship with air already heated by the ship we are trying to cool.

By judicious design we can arrange to dump much of this heated air to the combustion air chambers of the boilers. But today's ship, unless it is operating at relatively high percentage of available horsepower, uses considerably more ventilation air than is required for fuel combustion. Most of the vessel's life is spent at low boiler horsepower. So the rather sizable openings labeled "Forced Draft Blower Intake" on plans are, for most of the time of a ship's operating existence, exhaust openings. Woe betide the design engineer who looks at the labels on these openings and assumes that no air recirculating problems exist here!

Added to these problems of avoiding the use of air already heated within the ship is the not inconsiderable one of so locating weather intakes that surrounding structure does not serve essentially as a pre-heater to weather air. The combination of this and the recirculating problems creates such severe conditions that rarely can a ship be found in which some weather air intake openings are not drawing in air at temperatures already elevated above that of the weather. Further, the possibility of re-

location either of the offending opening or of the weather intake often does not exist except at prohibitively high cost in weight added to the ship.

A closure can be provided for any opening. But the weight of this closure will increase somewhat faster than the square of the opening's nominal cross-sectional dimension. Not only this—when the opening is closed it loses its primary function which is to permit that heat generated as waste heat within the ship to be carried to the weather. So inaccessible are many intake openings that closure operating gear, costly to install and maintain, and heavy in weight, must be installed. Closures thus defeat the very purpose of the opening and add most materially to the weight of the ship.

Everyone of the factors just discussed forces the use of heavy and complicated ventilation systems if removal of excess heat by weather air is to be undertaken. Each of them is increasingly an obstacle if quantities of weather air introduced into the ship are increased. Each of them, on the other hand, has minimum effect on sound engineering design if weather air quantities to be handled can but be decreased.

But heat loads internal to today's combat vessel are much larger than were they just a few years ago. So demands for weather air quantities go only in one direction—up.

If we are to attempt ventilation we find that we must handle increasing air quantities with less space assignable to duct runs and with these duct runs increasingly greater in length. To move the air we are driven to fans that more closely resemble compressors than conventional air movers. This resort to compressors has forced increases in fan horsepower and weight in geometric progression of increments. Further, it has brought to the fore another obstacle to acceptable operational condition of spaces—noise.

The high noise levels often encountered on the ventilated ship must be attributed to high fan pressures and the things that forced resort to these high pressures. It listens well to be told that good duct layout with nice straight runs will do much to eliminate noise. It is submitted that to achieve this layout faced with the need for long continuous duct runs in space limited as it is on the modern combat ship is an engineering feat beyond the capability of mortal man. It is quite true that elaborate and indeed effective noise attentuation measures can be taken. It is also quite true that resort to these measures forces up still further fan horsepower, system weight, system complexity and system space requirements.

The dictates of sensible engineering clearly point the path to the need for:

a. Reduction of the quantity of weather air which must be pumped into the ship. The ideal in this respect would be to have to pump no weather air at all. A modification of this ideal would be to permit all spaces to be fully operable for at least limited times even though no weather air is available.

b. Breaking up of duct runs into discontinuous segments in order to eliminate bulkhead closures and to minimize static pressure differential at access openings. The ideal in this respect would be to confine the duct run to the space from which heat was being removed.

c. The use of fans in each circuit which have the minimum possible horsepower. Obviously the ideal here is something more than zero horsepower since air must be moved, hence some pressure differentials are mechanically set up. Approach to the ideal is best made by maximizing the number of separate simple air circuits. Every step taken toward this ideal is a step taken to reduce air-

borne noise levels within the ship's envelope.

d. The absorption, from the space concerned, of the maximum possible amount of heat with the minimum possible amount of air handled.

Limits here are dictated by the nature of the space and the limits of human tolerance to low and high environmental air temperature. Obviously the greater temperature rise we can permit the less air need be handled. Obviously, further, the colder the air before heat pick-up the greater the amount of heat that can be absorbed before a limiting acceptable upper temperature is reached.

The engineer has available to him a method of providing habitable environmental air in all ship spaces which directly moves to meet these common sense engineering needs. The method is popularly known as air-conditioning. Simply by starting with the assumption that air-conditioning is a logical method of attack he finds:

a. That the need for weather air intake openings becomes entirely divorced from the problem of waste heat removal; and pertinent only to the problem of providing fresh air needed for the support of life and comfort of the humans who occupy the spaces. He finds these weather air needs to be small.

b. That he has available to him, for his free decision, an almost unlimited number of ways to provide discontinuous duct runs. This he finds is true because often he can group a few spaces served by one system and by so doing make truly spectacular progress toward saving weight at no cost in noise of system operation.

c. That, while he is still limited as to upper acceptable temperatures by the needs of men occupying the spaces, he is freed entirely from concern as to weather air temperature. He may design for removal of heat from equipment installed in the space with the minimum of restriction on intelligent and imaginative courses to pursue. He further finds that present conventional air conditioning methods, at the lower temperature ranges, stay within the limits of human tolerance for low air temperatures. If he needs even more air temperature rise than conventional methods provide he finds that less conventional systems give him almost unlimited possibility to obtain low air temperatures.

d. That the fans he must use have practically flea power requirements as opposed to the integral horsepower motors necessary to drive fans which must be used when waste heat is removed from the ship by ventilation.

The full and imaginative use of air-conditioning equipment now available, coupled with a firm abandonment of attempts to remove waste heat from the ship with weather air will lead to lighter, more rugged ships than we can possibly offer if we fail to take these steps. Manifestly, it is impossible to provide decent living conditions by further heating air which, as nature provides it, is already uncomfortably warm and is on the ragged fringe of being intolerable. If, in undertaking common sense engineering practice, we provide a comfortable ship, so much the better. But the approach to adoption of the practice needs to be that comfort provision is incidental to weight reduction, design simplicity and system reliability —that not in any circumstance is comfort provided at the cost of these all-important engineering factors.

REPORT OF THE COMMITTEE ON COST CONCEPTS AND STANDARDS

ACKNOWLEDGMENT

This article, in establishing standard definitions for costs, can be considered to provide a basis of common understanding among Management, Accountants and Engineers. It was published in the April 1952 issue of "The Accounting Review," published by the American Accounting Association.

I. INTRODUCTION

The Committee on Cost Concepts and Standards was reactivated for the year 1951 by the Executive Committee of the American Accounting Association. The Executive Committee hoped that in re-establishing this Committee, the ground work laid by previous committees would be carried forward to the benefit of the Association and the profession of accounting as a whole. The following statement prepared by the Committee is not to be construed as a statement sanctioned in every respect by the American Accounting Association. It is prepared solely as a statement representing the majority views of the 1951 Committee on Cost Concepts and Standards.

The 1951 Committee made an intensive exploratory study of the possibility of setting forth principles, concepts, and standards of accounting. Relative to the problem of setting forth principles of cost accounting, it came to much the same conclusion as did the 1947 Committee: "the use of the word 'principles' might well be avoided at this stage of the development. . . ." Other terms appeared more useful and meaningful. The 1951 Committee was reluctant to take the responsibility of setting forth guides to action which might be either so general as to have little applicability to the concrete situation or to be so specific as to have limited scope.

The 1951 Committee stressed in its studies the possibility of defining and clarifying a multitude of concepts that have over the years been coming within the sphere of the cost accountant. As an approach to offering positive guidance to current cost accounting problems, the Committee felt that this afforded the best opportunity to be of service at the present time. As a consequence, major stress of the 1951 Committee is upon cost concepts and related business decisions and policy and, to a lesser extent, upon principles or standards of cost accounting.

Significance of Cost Accounting.—Cost accounting is a tool of management. In so far as it aids management in the preparation of general financial statements, it supplies data which may be

used eventually as a guide to the overall efficiency of an organization, the relative efficiency of a firm to other firms in an industry, or the relative profitableness of present pursuits of management as contrasted to alternative opportunities. The data of the cost accountant utilized in conjunction with those of the statistician, the economist, the engineer, and others may be employed in efforts to maximize the profits of a firm. Operating cost data may be used in budgeting and to provide management with a basis for controlling costs. A host of additional data, partially or wholly supplied by the cost accountant, will be pertinent to a broad area of decisions relating to choice. Cost data when properly utilized can do much to maintain or increase the income potentialities of a firm.

Relationship to Financial Accounting.—Cost accounting is not an isolated phenomenon separated and divorced from other areas of accounting. Rather, it draws from financial accounting basic recorded facts, and, in turn, furnishes the financial accountant needed cost information. Cost accounting becomes differentiated from general or financial accounting when, in addition to providing data for financial accounting purposes, it provides management with a host of cost measurements pertinent to problems of control and decisions relating to alternatives.

Objectives of Cost Accounting.—The objectives of cost accounting are:

a. To accumulate costs necessary to the preparation of general financial statements.

b. To provide various levels of management with cost data necessary to the control of cost.

c. To provide management with cost information necessary to business decisions and related policy.

The first objective relative to costs required in the preparation of general financial statements is not necessarily stated in the order of its importance among the objectives of cost accounting. It is listed in its present order because the Committee felt that this objective represents the connecting link between general and cost accounting. By this objective is meant the gathering of costs by product or time period to facilitate the preparation of periodic statements and the process of budgeting. This objective concerns the cost accountant measuring costs related to goods and services and to a period of time.

The second objective, "To provide various levels of management with cost data necessary to the control of cost," refers to the work of cost accounting in providing cost information helpful particularly to technical management, factory, distribution, or office. Such data will be supplied to assist management to control operations. Especially does this objective apply to the gathering of information most useful to a management interested in obtaining optimum use of men, machines, and materials in the light of a given demand for the products or services sold.

The third objective, "To provide management with cost information necessary to business decisions and related policy," points to a new and dynamic phase of cost accountancy. Although the first two objectives given relate to cost data which may be useful in the realm of business decisions and policy, this objective refers to business decisions and policy requiring cost data of a specialized nature which are not ordinarily encompassed within the scheme of general financial accounts or included within the sphere of cost measurements useful for technical control purposes. Consequently, this objective points to the necessity of measuring costs in a multitude of different ways, particularly measurements which are useful only to the decisions with reference to which they were drawn.

Scientific Approach to Cost Computation and Measurement.—Scientific methods in general involve the establishment of valid conclusions on the basis of relevant facts. The valid conclusions sought may be anything from a fundamental general law to the determination of an exact measurement. It is required that the scientist ascertain what facts are relevant to the conclusions sought, that he seek those facts, observe them competently, and measure their significance. Facts themselves are not only observed phenomena, but also the relationships between phenomena. The cost accountant can do no less than apply this scientific method to whatever extent possible within the area in which he renders service.

II. COST CONCEPTS

There is a wide diversity in the use of terms and concepts employed in cost computations. This diversity is the result of a variety of causes. One of these is the different conditions under which costs may have to be computed. Economists have developed some concepts related to cost. Accountants have developed some that are applicable to the solution of their problems. Engineers have to consider costs, and their concepts and terminology have been developed according to their needs. Many persons have faced cost problems without training or wide experience, and consequently have improvised concepts to serve limited purposes. Also, writers in the field of cost accounting, not content to follow others, often appear to have sought to introduce an element of originality into their statement without giving thought to potential confusions.

In stating concepts, certain requirements should be met as far as possible. A concept already recognized should be stated in terms in which it has become generally familiar, as long as the term is clear and readily understood. The concept should be stated and used in such a manner that there is the least possible doubt concerning its meaning. It should be stated in terms consistent with the use to be made of it and with the actual phenomena with which it deals. Successful fulfillment of these requirements in any statement of concepts indicates the achievement of a high ideal. Even a substantial approach toward fulfillment will be a worthy accomplishment. Concepts develop as the need for them arises; and as needs change concepts may also change, or may even have to be abandoned in favor of more useful ones. This has been true in the precise natural sciences and most certainly it must be true in accounting and business administration. The following statement of concepts is therefore made with full awareness of its tentative nature.

COST is foregoing, measured in monetary terms, incurred or potentially to be incurred to achieve a specific objective.

The term "cost" is a generic term purposely defined broadly so as to encompass all the various types of cost employed by the cost accountant. When the term is specifically used, it is always with reference to the object costed—it has to do with the cost of something. There is also implicit in the use of the term the fact that cost is incurred by some person or group of persons. If the above definition of cost is accepted, then a logical definition of cost accounting would be:

COST ACCOUNTING is the measurement of cost in accordance with the needs of business management.

HISTORICAL COST is cost measured by actual cash payments or their equivalent at the time of outlay.

Such measures of cost are verifiable by records of transactions that have occurred or by commitments definitely made. Historical costs are ordinarily the relevant costs to use in connection with general accounting. They have no relevance to administrative decisions concerning the future except to the extent to which the past may throw light on the future. The terms historical cost, original cost, and actual cost are often used interchangeably, and such usage will be followed in this report.

FUTURE COSTS are costs expected to be incurred at a later date.

Future costs are significant to decisions of management concerning operations in the future. To a limited degree, the past may be projected into the future, but, by and large, experience with the past merely provides management with the skill to predict, with varying degrees of certainty, and to draw conclusions on the basis of these predictions. The extent to which historical cost data have provided pertinent information in the past, and the accuracy with which various cost relationships have been established, will strongly affect the extent of management's probing into the future and the reliability of its predictions.

REPLACEMENT COST is cost in the present market.

Where the objective of management is the acquisition of data relevant to a current valuation of assets or of the preparation of a statement of income in economic terms, this concept is a useful one.

STANDARD COSTS are scientifically predetermined costs.

A standard is an established measure expressed in terms of definite specifications and applicable within a given area or to a given situation. The standard cost of a product or operation is the cost of that product or operation if the production has taken place or if the operation has been carried out strictly in accordance with certain specifications which were established as standard. In the production of goods, specifications are made and thus standards are set with respect to quantities of materials to be used and the acquisition cost of those materials, labor time to be used and the wage rates specified therefor, and overhead to be incurred and charged under certain specified conditions.

Since standard costs may serve management for a number of purposes, the standards that are constructed are established in terms of the purposes that they are primarily to serve. There can be, therefore, no one standard cost of anything, but there may be several different standards to whatever extent needed to serve the purposes at hand. The meaning of cost standards in a given situation and the interpretation of variances therefrom presupposes an understanding of the standards used in relation to the purposes they primarily serve.

ESTIMATED COSTS are predetermined costs.

Estimated costs differ from standard costs in that less care and objectivity are employed in their measurement. Although they may be utilized in lieu of standard costs, less reliance can be placed upon them in contrast to the use of more scientifically predetermined costs.

PRODUCT COST is cost associated with units of output.

Such costs are particularly pertinent to the problem of financial statement preparation. They are utilized in establishing inventory values and in ascertaining periodic profits. They may be used for general pricing purposes and for ascertaining the profitableness of different lines of product or different services rendered. Depending upon the objective in mind, such costs may be measured in terms of historical, future,

replacement, standard, or estimated costs.

PERIOD COST is that cost associated with the income of a time period.

Narrowly applied, as a contrasting term to product cost, this concept refers to all costs except product costs that are charged against the revenue of a time period. Used broadly, period cost refers to all charges against the revenue of a time period, including product costs.

DIRECT COSTS are those costs obviously traceable to a unit of output or a segment of business operations.

Such costs have particular significance in the area of determination of product costs and in the development of aids for the control of business operations. It must be kept in mind that any classification of cost into direct and indirect is relative, that many costs, although not traceable directly to an object being costed, are actually components of the object being costed. The greater the number of costs directly assignable to the object being costed, the more valid will be the cost accountant's efforts in supplying accurate cost data useful to management.

PRIME COSTS are the labor and material cost directly traceable to a unit of output.

In the historical development of cost accounting, the early use of this term was synonymous with the term "direct costs." However, with the development of more refined techniques of cost measurement, a greater number of costs may now be classified as direct.

INDIRECT COSTS are those costs not obviously traceable to a unit of output or to a segment of business operations.

Thus defined, the term indirect costs is synonymous with overhead costs. These costs are commonly associated with units of output by means of an overhead rate or rates. Prior to such association, various bases of allocation are employed to allocate indirect costs to operations, processes, or departments. The relativity of the terms direct and indirect should be clearly understood. Whereas certain costs may be indirect relative to product, they may be direct to other objects, such as a machine, an operation, or a department.

FIXED COSTS are those costs which do not change in total as the rate of output of a concern or process varies.

VARIABLE COSTS are those costs which do change in total with changes in the rate of output.

The terms fixed and variable must be conceived as relative rather than as absolute terms. If a sufficiently large change occurs in the rate of output, practically all costs may be caused to vary. On the other hand, if the change in output is small, it might be difficult to find and measure any change in costs. Consequently, it is generally understood that the terms fixed and variable as employed in a given case apply to an assumed or specified range of output. Variable costs need not vary in direct proportion to the rate of output. Depending upon the cost components involved and their relationship to output, the patterns of variation may be many and diverse.

The terms semi-variable and semi-fixed costs have come into use in recent years. Some accountants distinguish rather vaguely between the two terms, but the general concept of these terms grows out of the fact that there are some elements of cost that apparently remain fixed over a relatively small range of variation in output and then abruptly change to a new level, remaining fixed again over another short range of output. This situation may better be described by calling these same costs variable, but noting that they do not vary continuously with output but rather

by steps. It is proposed that a clearer expression of these conditions would be to preserve the terms fixed and variable costs and then to recognize two conditions of variation, namely, practically continuous variation and intermittent variation. Thus variable costs would be classified as continuously variable costs and intermittently variable costs. Very few costs except component material costs conform to the concept of continuous variability. Even then if product units are large and the component material units large, the costs will vary by perceptible quanta.

OPPORTUNITY COST is the measurable advantage foregone as a result of the rejection of alternative uses of resources whether of materials, labor, or facilities.

Since the decision to employ resources for one purpose or in one manner and to reject others is made for the future, it follows that opportunity costs, when they are relevant to a decision, are a type of future costs.

IMPUTED COSTS are costs that do not involve at any time actual cash outlay and which do not, as a consequence, appear in the financial records; nevertheless, such costs involve a foregoing on the part of the person or persons whose costs are being calculated.

In many cases, these foregoings may be measured as opportunity costs. Examples of such costs are salaries of owner-operators of single proprietorship or partnership enterprises, rental value of owned properties, and interest on invested capital. Although such costs do not constitute historical costs and although they may at times not be precisely measurable, they may be vitally significant facts in making business decisions. Decisions so affected may involve the choice of going into business for one's self as an alternative to working for salary, or a decision to apply a portion of one's capital to acquiring a building instead of renting and using that capital in some other way. The inclusion of imputed costs also becomes important in the making of certain cost studies involving comparisons between concerns operated as corporations with others operated as personal enterprises or between the use of a machine process and a hand process.

CONTROLLABLE COSTS are those costs subject to direct control at some level of managerial supervision.

These costs are not the equivalent of variable costs. They may include fixed costs. For example, a plant service department should be able to control the cost of window washing even though window washing may be classified as a fixed cost. On the other hand, power cost may represent a variable cost, but because of the impracticability of metering power to certain operational areas, such costs will be uncontrollable in these areas. Depending upon the departmental area involved and techniques available for cost measurement, a specific cost may be classified both as controllable and uncontrollable. To an unmetered department power usage may be uncontrollable; to the department producing power, power production cost may be controllable completely or in part.

UNCONTROLLABLE COSTS are those costs not subject to control at some level of managerial authority.

Rent cost may be subject to the control of that management which has the authority to make and renew leases. On the other hand, rent cost would be uncontrollable by a departmental supervisor who has been assigned a certain amount of space. At the level of the departmental supervisor, rental cost is uncontrollable.

JOINT COSTS exist when from any one unit source, material or process, there are produced units of goods or services which have different unit values.

These "units of goods or services" are termed joint products. The relative

proportions of joint products may vary considerably in different situations ranging all the way from scrap to products of approximate equality. Usually joint products of minor significance are classified as by-products. The joint costs are the total costs incurred up to the point of separation. Joint products may exist within a business even when end-products or services produced are not themselves joint products. When the several unit areas of a building have different rent values, the rental cost of the building as a whole is a joint cost. Although in practice various expedients are used to apportion joint costs among products or services, there is no known accurate method of joint cost apportionment.

SUNK COSTS are historical costs which are irrecoverable in a given situation.

A classic illustration of a sunk cost is the cost of drilling a dry oil well. The recovery of cost is contingent upon the yield of the well. Should the yield be insufficient to recove the costs incurred, such costs will not be relevant to future decisions made with respect to the well. The essential feature of sunk costs in making managerial decisions is that they may be irrelevant either in whole or in part.

DISCRETIONARY COSTS, often termed escapable or avoidable costs, are those costs which are not essential to the accomplishment of a managerial objective.

Many costs are of the type that must be incurred in order to attain an ultimate objective. Others may not be essential. For example, it may be demonstrated that keeping walls of a factory department painted may have some effect on output, directly or indirectly. However, it may not be necessary to paint those walls. It may be merely a matter of administrative choice. Also, if the walls are painted, it is a matter of discretion as to how often the painting shall be done. The same may be said of many other costs. This concept may have considerable significance when study is made of cost behavior since obviously some costs behave as they do because of administrative decision.

POSTPONABLE COSTS are those costs which may be shifted to the future with little or no effect on the efficiency of current operations.

These costs differ from discretionary costs in that they must be incurred at some date. Examples of postponable costs are repairs and overhauls to machinery and equipment which although essential to continued efficiency may be deferred with little or no effect on current operations.

OUT OF POCKET COSTS are those costs which with respect to a given decision of management give rise to cash expenditures.

These costs are relevant where complete product costs have little or no relevance. In situations where management is interested in whether a particular venture will be sufficiently profitable to carry at least the cash expenditures occasioned by the venture, this concept has significance.

DIFFERENTIAL COSTS are the increases or decreases in total cost, or the changes in specific elements of cost, that result from any variation in operations.

Most frequently this concept is applied to changes in total cost resulting from changes in the volume of output. When so applied, the concept becomes practically synonymous with marginal cost. However, the concept has a much wider application. For example, it is unquestionably applicable to the costs incurred in processing and disposing of a by-product, which costs would not have been incurred had the material so processed been permitted to go to waste. Also, it is evident that differential costs may, under certain conditions, consist

only of variable costs. However, in making some decisions, differential costs may also contain elements that are or will become fixed. Adding a new process or changing a process so as to require additional equipment are illustrations. Differential costs are usually thought of as increments. They also have their decremental aspects as well. A reduction in volume of output will be accompanied by some reduction in total cost. In most business decisions involving adjustments of policy, differential costs are the most relevant costs.

III. COST ACCOUNTING AND FINANCIAL ACCOUNTING

A basic objective of cost accounting stated earlier in this report is "To accumulate costs necessary to the preparation of general financial statements." In accomplishing this objective, cost accounting draws from data contained in the basic financial records. However, it refines and utilizes such data to facilitate (1) the preparation of the operating and financial budgets, thereby assisting in the establishment of a profit goal, and (2) the determination of periodic profits as well as costs related to inventories, thereby providing an over-all check on the attainment of the profit goal.

ESTABLISHMENT OF A PROFIT GOAL

Budgets are essential to the establishment of a profit goal. They may attempt to set up in advance a plan of action either for the immediate future or a longer period of time. A master budget consists of financial, sales, production, selling expense, administrative expense, and other budgets. Each budget, or its subdivision, is made the responsibility of an executive department head, or foreman. Reports are issued by the cost accounting or budget department to highlight actual performance in comparison with limits set by the budget. Budgetary amounts are based partly on past experience and partly on expected future conditions.

Successful budgeting requires the detailed collecting, recording, and summarizing of transactions dealing with all components of cost. The achievement of this task revolves around the chart of accounts, the cost system, and the company's policies regarding the treatment of cost elements. As details are reported to department heads and foremen, management is able to observe and bring into focus the various segments of the total picture as laid down in the budget. The progress toward financial year-end success is constantly guided and controlled by actions taken daily, weekly, and monthly by cost accounting techniques and procedures. Periodically, actual results will be contrasted with a revised budget, i.e., the original budget reconstructed in the light of actual happenings.

The chart of accounts is the vehicle to direct the financial transactions of the business into proper accounting channels. The coding or numbering system should de designed to permit efficient recording and prompt reporting. At times, data gathered in the accounts may have to be further subdivided for additional analysis. This is particularly true in connection with distribution costs. The chart of accounts should allow for the preparation of annual financial statements in harmony with planned intentions as shown in the budget. At the same time, it should provide the cost department with the possibility of reporting and analyzing the costs for managerial guidance throughout the fiscal period without requiring too much additional analysis.

Closely related to the chart of ac-

counts is the cost system. Basically, two types of cost systems exist: the actual cost and the predetermined or standard cost system. However, the line of demarcation between each type in modern costing may be tenuous. An actual cost system makes use of predetermined figures, particularly in connection with the charging of manufacturing expenses to jobs, products, and departments. Most standard cost systems include the determination of actual costs.

DETERMINATION OF PROFITS

Cost accounting is greatly influenced by dogmas, doctrines, principles, and conventions generally adhered to or practiced by the profession of accountancy as a whole. It is the purpose of this section to examine these dogmas, doctrines, etc., which are particularly significant to the cost accountant's efforts in the area of income determination and the relation of costs to inventories.

The Dogma of Consistency.—Consistency refers to the use of accounting methods and procedures followed with such uniformity that comparisons among time periods are facilitated. In dealing with relationships between cost accounting and financial accounting, it is assumed that costing methods are consistent with financial accounting methods. Such an agreement establishes the often expounded and desirable tie-in of the cost accounts with the financial accounts. However, as a forecaster and an interpreter, the cost accountant's role is hampered if a narrow interpretation of consistency is made the cornerstone of his activities. Many reports and analyses prepared by the cost accountant come from sources outside of the records, and such data may not be based upon historical cost. Consistency, in so far as the cost accountant's efforts are concerned, must refer to presenting data having reference to similar situations in comparable form.

The Doctrine of Materiality.—This has to do with the significance of amounts. In cost accounting this doctrine plays a part in connection with the ultimate disposition of over- or under-absorbed overhead, standard cost variances, unusual gains or losses, and many other items.

The cost convention.—In the application of principles of consistency and materiality, cost accounting is strongly influenced by such accounting conventions as the "cost" convention and the "period" convention. The term "cost" as usually employed in financial accounting refers to the use of historical cost as a basis for transferring values from one objective to another, from one classification to another, and from one process or activity to another. Although historical cost is important for financial accounting purposes, it must be kept in mind that costing is rarely based upon such cost. The use of original costs in the costing process is always accompanied by estimates and apportionments that are based upon assumptions. Even if the actual costs are used in charging material and labor costs to products, manufacturing expenses are often taken to product via a predetermined rate. Therefore, as a matter of fact, pure historical costing does not take place. Further, for managerial guidance in business tactics and price-setting, the original cost is seldom helpful. Replacement or future costs will need to be substituted. However, at the present time, any conversion of historical costs to replacement or future costs should be supplementary with respect to formal financial statements based upon historical cost.

Convention of an accounting period.—The convention of an accounting or fiscal period deals with the desirability of separating the life of an enterprise into convenient time spans, usually

years, for the purpose of reporting to owners, investors, and government agencies. This accounting convention, which has as its objective, comparableness, has led to two accounting classifications significant to the relationship between financial and cost accounting:

(1) Capital and revenue expenditures. This classification looks upon expenditures as belonging to one of two groups. The "capital" expenditure group considers the cost as belonging essentially to more than one accounting period. Periodically, therefore, a portion of this cost is separated from the basic capital charge and transferred as a charge against current income. Other expenditures considered directly applicable to the period under review are taken as deductions from current revenues.

(2) Product and period costs. This division of costs represents basically a refinement of the capital-revenue classifications for purposes of cost accounting. Revenue charges are related either directly to the product (product cost) or directly to the revenue of the period in which incurred (period cost). No hard and fast rule can be given with respect to this two-fold division. Usually the classification is based upon a company's or industry's experience, intentions, convenience, and expediency, or upon instructions issued by regulatory bodies. Where material amounts are not involved, errors relative to the classification of some revenue debits as either product or period costs have little significance. However, where amounts are material, the doctrine of consistency, broadly interpreted, should be a guide to the proper handling of these charges.

Direct and indirect costs.—The product-period cost classifications are greatly influenced by divisions of cost on the one hand into direct and indirect and on the other into fixed and variable. Direct costs are assumed to constitute inseparable parts of the product unit cost. Indirect costs arise where there appears to be no immediately measurable relationship between certain expenses and product. Factory overhead, distribution expense, and administrative expense are subclassifications of indirect cost. In order to obtain as complete a cost of product as possible for financial accounting purposes, factory overhead is ordinarily related to product by means of a rate or rates. Some attempts have been made in recent years to do with distribution expense much the same as has been done with manufacturing expense: to relate such costs to products sold by means of rates. In contrast to factory overhead, however, it is difficult to relate causally such costs to product.

Relative to management's problems in connection with the control of cost through budgeting, costs classified as indirect for product costing purposes may be direct for control purposes. The test of directness in this latter case is whether the expense is traceable to the supervision of some responsible executive. It should be kept in mind, however, that even though traceable directly to some supervisory area, the cost may not be subject to the control of the supervisor. (See definition of controllable costs.)

Fixed and variable costs.—The fixed-variable classification of cost affects the period-product classification in that many accountants feel that fixed costs should be charged to product by means of a normal overhead rate or rates. Depending upon the particular concept of normal employed, e.g., practical capacity, normal utilization of plant, or merely a normal seasonal rate, varying amounts of fixed cost will be taken to product. Also, amounts of year-end capacity variances will differ depending upon the type of overhead rates employed. The classification of costs into fixed and variable, and the selection of a particular concept for normalizing fixed cost will seriously affect the product-period cost classification.

Standard costs.—In many respects, problems in normalizing fixed overhead costs are inherent in the normalization process that takes place when standard costs are utilized and such standard costs are used as an integral part of the entire system of accounts. Where product costs are computed on a standard cost basis for financial accounting purposes, the particular concept of standard employed by the individual firm will affect the product-period cost classification. Ideal or near-ideal standards tend to give rise to variances which are commonly charged either to cost of goods sold or to profit and loss. On the other hand, the more standards are established with reference to practically attainable goals, variances arising tend to represent exceptions. However treated these exceptions will have less effect on the product-period classification than variances arising when ideal or near-ideal concepts of standard are employed.

IV. THE ROLE OF COST ACCOUNTING IN COST CONTROL

An important function of cost accounting is to provide management with data for measuring the performance of its organization. From such data an evaluation of results can be made and action taken, as necessary, to improve performance. There is a great deal of economic significance in the application of cost accounting to a cost control program. Increased productivity and profits should stem from improved organizational performance.

In connection with a cost control program, cost accounting provides the medium through which:

(1) Measurement and evaluation is made of organizational performance.

(2) Measurement and evaluation is reported to responsible management.

(3) Follow-up on the remedial action of management is carried out in order to determine the degree of performance improvement that has taken place.

Fundamental requirements of a cost control program.—The following requirements are applicable to all productive areas of an organization, such as purchasing, clerical, manufacturing, distribution, or any other functional area essential to business operations:

1. Establishment by management of responsibility for cost incurrence and control.
2. The requirement that the cost accountant will follow up on actions taken by management to measure the results of such actions.
3. Development of standards to measure most effectively the efficiency of performance.
4. Accounting procedures for the accumulation of costs to facilitate the measurement of performance in terms of standards.
5. Ascertainment of departures of actual cost from standard costs and analysis of such departures into basic types.
6. Presentation and explanation of variances in terms of underlying causes accompanied by an analysis of variance according to responsibility.
7. A reporting plan designed to provide the various levels of mangement with the results of the measurement of performance in terms of standards.

Responsibility for cost incurrence and control.—This requirement may be attained through the assignment of responsibility to cost incurrence areas. There should be a delegation of responsibility from top levels of management to lower levels. The basic mechanics of such assignments will vary with the particular organization and even within the various areas of a given organization. Such a flow may be illustrated by

a steel plant. At the top is a vice-president in charge of operations. Below this executive are the various area supervisors, such as coal mining, blast furnace production, open hearth production, and the various finishing operations. Subordinate to these divisional supervisors are individual unit superintendents, and finally, at the bottom rung of the management ladder, are the foremen and others immediately responsible for operational performance.

With such a flow of responsibility established, cost accounting then may apply its techniques for accumulating costs in order to measure the performance of the various responsibilities. This measurement should be accomplished in a manner which will permit upper echelons of management to ascertain the performance of subordinates. It is through such measurements that all levels of management are held accountable for performance.

Requirement of authority for follow-up.—Essential to the proper functioning of cost accounting in its control job is the presence of authority and organization for follow-up on performance measurement. The substance of this requirement is that, subsequent to the first analysis, there must be a second measurement of performance and report thereon. Through such remeasurement, an evaluation can be made of the first remedial action, and further corrective measures can be taken if necessary. Provision for secondary analysis and reporting is one of the most important steps essential to the successful accomplishment of the cost accountant's part in cost control. It should be apparent that a one-time analysis can be wasted effort unless assurance is made of proper corrective action. Such assurance is gained through follow-up analysis.

Development of standards.—In order to provide a basis for measuring organizational performance, it is requisite that standards be developed. Such standards may take the form of relatively precise engineering standards or they may be accounting estimates based on accumulated monetary histories of past performance modified for known and expected changes. A standard, to be effective for cost control purposes should be expressed in the unit most applicable to the performance being measured. Typical of the units that may be utilized are tons of metal, invoices processed, calls per sale, and hours worked. Obviously, the unit used will vary from firm to firm, industry to industry, and within a given firm. Sound judgment must be exercised in selecting the unit of expression, for selection of an improper unit can result in distortions in reporting and the continued existence of conditions of poor performance.

The standard should, insofar as possible, represent attainable performance under existing operating conditions. There are many techniques available for development of an attainable type standard. However, such techniques are beyond the scope of this statement of fundamentals.

It is essential that effective standards be presented in terms of a monetary unit. This is necessary in order to determine the significance of the object being costed and the most efficient direction of remedial efforts. However, where the management is closely connected with technical operations, standards expressed and utilized in non-monetary terms will often provide insights into causes of poor performance not possible from monetary standards. Both types, monetary and non-monetary standards, are of importance when standards are utilized to aid in performance control.

Procedures for matching actual costs against standard.—A further requirement for effective cost control is that an account classification be provided which will relate actual cost incurrence to standard. Such classification should be designed to fit the needs of each responsibility measured, and, so far as

possible, similar or like responsibilities in different operational areas should have like account classifications. When this is done, usable comparison of performances can be made between similiar responsibilities.

Variance determination.—Fundamental to cost accounting as an aid in cost control is the proper measurement of actual production cost departures from established standards of cost incurrence. Such an analysis should separate favorable and unfavorable variances so as to avoid offsetting poor performance against good performance. Further, if the particular favorable or unfavorable variance is a summation of several tendencies or basic influences, these, in turn, should be differentiated and set forth. Finally, there should be a classification of variances as controllable or uncontrollable.

Segregation of production cost departures into causal categories.—In order to provide management with the means to evaluate performance measurement, it is necessary that an analysis be made of departures according to cause. Causal analysis does not refer to variance analysis, rather it has as its object the relating of variances to underlying causes or reason for departures. An example of this type of analysis is to be found in the case of poor labor performance in a rolling mill. This may have been caused by any number of difficulties such as the use of off-standard materials, break-down of mill, or simply poor worker output. Ascertainment of cause opens the way to corrective action. Failure to determine such causes initially often makes desirable remedial action impossible, for, at a later date, cause of poor performance may be indeterminable.

Provision for a reporting plan.—In order to accomplish the objectives of a cost control program, a reporting plan to meet the needs of various management levels is needed. Reports should be prepared in greater detail the lower the level of management to which reports are made. Provision should be made whereby detailed information provided lower managerial levels may be readily consolidated into summary reports for upper levels of management.

V. SPECIAL COST STUDIES

This section deals with the cost accountant's efforts "To provide management with cost information necessary to business decisions and related policy." Very few generalizations apply to this phase of the cost accountant's work. Essentially it represents an attempt to meet needs of management not met in those areas of cost accounting covered in sections III and IV of this report.

In accomplishing this objective, the cost accountant should ascertain the following clearly: (1) what he is attempting to cost; (2) the purposes to be served by his costing; (3) the pertinent costs and their units of measure relevant to the purposes to be served; and (4) how and by what methods costs are to be assigned to the object or objects being costed. The following discussions represent the more common cost studies required of the cost accountant:

Cost and volume variation.—A break-even analysis is of significance to management as an analysis of the future. The total forecasted costs and their components are generally the costs pertinent to cost and volume studies. In attempting to measure cost and volume relationships, costs are predicted within a possible or probable volume range. Within this range each cost component is examined to determine the nature and the extent of its variation with volume. At this point, it is determined which costs are fixed within the volume range considered and which are continuously variable. The variation of

these latter costs within a given range is computed. It also is determined which costs are intermittently variable, the points at which the variation occurs, and the extent of the variation.

In considering intermittently variable costs, it should be emphasized that some of the points at which variations take place may actually be a matter of discretion on the part of management. This may also be true of the extent of the variation. The cost accountant should have reasonably accurate knowledge of management's intentions with respect to more or less completely discretionary costs. Cost variation is more subject to modification by management than is generally assumed. In a given enterprise, there is probably no such thing as a mathematical overall cost function in terms of volume.

Decisions to add a new product or to abandon a product.—Assuming that a plant has the capacity to add a new product, the decision will require consideration of differential cost only. Such differential cost will include not only additional variable costs but also any addition to fixed costs that may have to be incurred.

If the question is one of dropping a product without substitution of another, the relevant costs are those that can actually be avoided by so doing. Except to the extent to which fixed costs may be reduced by disposal of equipment used in its production, these costs are usually variable costs only. The relevant fixed costs—and this applies primarily to depreciation—will then be based not on present book value of equipment to be disposed of, but its disposal value.

If the issue is the abandonment of one product and the substitution of another, the decision will demand consideration of opportunity cost. This resolves itself ultimately to determining the effect on total net revenue likely to result from making the change.

Cost and expansion of facilities.—If expansion of operating facilities is contemplated, such as the acquisition of warehouse space which may seem to be needed, the relevant costs are the total future costs to be incurred including all the costs of construction or purchase. Under foreseen conditions, these costs may be recoverable from the use of the facilities. If it should subsequently happen that these costs cannot be fully recovered through revenues, the enterprise may as a result, say of partial use, find itself facing a sunk cost. The measure of such sunk cost is the difference between book value at any time and the disposal value of the facilities. Whether or not the facility can be profitably used at less than full capacity will depend not on its book cost but its opportunity value (disposal price). Hence future depreciation for such use will be depreciation based on disposal value and not on original cost.

Cost and replacement of equipment.—When the replacement of existing serviceable equipment with potentially more economical equipment is being considered, it is necessary to compare costs under two sets of conditions. The relevant costs on the equipment to be displaced are based on its realizable value. The depreciation on the old equipment, if it is to be used, must be based on that realizable value over its remaining life in use. The difference between this and its present book value is a sunk cost and therefore irrelevant. In calculating the cost of using new equipment, interest on the differential investment—that is, cost of the new less realizable value of the old—must be considered. This has the same effect as including interest on both investments in making the comparison. Operating costs of both pieces of equipment must also be determined for comparison. This is one point at which the concept of imputed cost must be applied.

Displacement of manual operations by mechanical equipment.—When consider-

ation is being given to displacing manual operations with the use of mechanical equipment, such as in the installation of materials handling equipment to displace manual handling, a comparison of operating costs under the two methods is essential. It is also necessary to consider imputed interest on investment on the new equipment at a rate representing the return that could be realized from the best available alternative use of the added capital required.

Joint cost situations.—There are some facts that management may need relative to joint products. Among these facts are:

1. Valuation of inventories and cost of sales of joint products.
2. The extent to which the individual joint products contribute to the net profit of the enterprise.
3. The facts needed in order to make various decisions relating to the processing or distribution of the individual joint products.
4. The facts needed to make decisions with respect to changes in the joint process itself.

In view of the fact that no known accurate procedure exists for the assignment of joint costs to joint products, it is impossible to value accurately on a cost accounting basis any joint product inventory. A method of valuation that is satisfactory for balance sheet purposes and for calculation of inventory as of a given date is current market value less necessary future costs to process and market, less allowance for costs such as general selling expense and administrative expenses generally chargeable during the period in which sales take place, and also less normal or reasonably expected average net profit as a percent of sales. This is not cost, but it is a fair and reasonable and widely acceptable basis for inventory valuation for financial accounting purposes.

The exact total cost of sales for any one of a group of joint products turns out to be irrelevant to any business decision that may have to be made with respect to such product with the possible exception of a contract in which selling price may be established on the basis of cost. In that case the method of calculating cost whether logical or arbitrary should be specified as a part of the contract. If such specification were omitted and if the matter became subject to adjudication, judgment would consider first current practices in the area involved and with which the parties are presumed to be familiar.

The extent to which any joint product contributes to the net profit of an enterprise is measured by its sales less the specific costs incurred on such product exclusive of any part of the joint cost and general or non-product expenses. This difference may be termed the specific or direct contribution of the joint products to the profits of the enterprise. Specific product costs include all costs of processing or distribution that are incurred because the product is processed and sold and which would not be incurred if the material were allowed to go to waste. It is obvious that if a given joint product were not processed and sold at all its contribution to net profit would also be foregone.

This situation must be distinguished from one in which, after equipment or facilities have been provided, the question of continuing processing is raised. In that case only the actual differential cost at the time becomes the relevant cost.

In making policy decisions affecting individual joint products, the cost taken into consideration must be only the specific costs chargeable directly to the products. No share of joint cost has any relevancy whatever with respect to such decisions. A proposed change in processing a product in order to increase its sales value would require consideration of the resulting effect on cost and

on sales revenue. The joint costs remain the same and have no bearing on the decision.

In case of a contemplated change in the separation process itself, the facts that would be considered are first the total change in the joint cost itself and second the net change in the combined direct contribution of the several joint products to the over-all profits of the enterprise. Again, no assigned joint cost can be relevant.

The foregoing statements deal only with joint cost computations and analysis and have no bearing on how net results shall be presented in published or general statements.

Joint costs exist not only in relation to end-products of an enterprise but also as components of the costs of non-joint products whenever any cost component within the enterprise exists as a joint cost. Thus rent or its equivalent in the case of a department store becomes a joint cost component of the departmental operations by virtue of the fact that rental cost of the building as a whole when divided among the departments is found to apply to space units having different values. Thus costs of rental assigned to a given area within such a building turns out to have no relevance to any decision that may be made with respect to the use to be made of such area.

The cost accountant in making cost allocations must be alert to discover whether any more or less arbitrary allocations that he may be making may not involve actual joint costs. Should this turn out to be the case, the reliability of his cost figures for management use becomes subject to suspicion.

The 1951 Committee on Cost Concepts and Standards consisted of the following members:

George W. Lafferty, Frazer and Torbet, Houston, Texas.

Adolph Matz, University of Pennsylvania.

Harry J. Ostlund, University of Minnesota.

Vern Vincent, University of Tennessee.

Lawrence J. Benninger, Chairman, University of Missouri.

MANPOWER UTILIZATION

CAPTAIN R. E. W. HARRISON, USN

THE AUTHOR

was born in Manchester, England in 1893. Educated at the Manchester College of Technology. Served in World War I in the Royal Engineers and saw service in Egypt, Gallipoli, Sinai, France and Belgium. As an industrial engineer designed and supervised the building of the precision grinding machinery manufacturing plant of the Churchill Machine Tool Company of England, prior to citizenship in the United States. In 1926 Director of Engineering, Cincinnati Grinders, Cincinnati Milling Machine Company. In early '34 appointed Chief of the Machinery Division of the U.S. Department of Commerce. In late 1935 became Vice President, Chambersburg Engineering Company. Transferred in 1935 from Specialist Engineering Branch U.S. Army Ordnance to Lieut. Commander in U.S. Navy as Production Engineering Specialist. Was assigned to active duty as Machine Tool Procurement Officer in the Assistant Secretary's office July 1940 and served in this capacity for two years. Subsequent duties included Special Assistant to the Under-Secretary, operation of the seized Norden Bombsight Plant at Elmira, and the Howarth Marine Thrust Bearing Plant, Philadelphia, operating in both cases as Deputy Officer in Charge for Chiefs, Bureau of Ships and Bureau of Ordnance. Captain HARRISON is a Fellow of the American Society of Mechanical Engineers, and the Royal Society of Arts—also a full member of all other leading engineering societies in U.S.A. and Europe. At present on duty in the Navy Department as Industrial Engineering Officer in the Field Activities Division of the Bureau of Ships.

INTRODUCTION

Certain basic principles, as suggested guide lines in dealing with the manpower utilization problems of today, are herein discussed in the belief that these data, emerging from thirty-five years of practical experience in more than twenty different countries, can be of service to the engineers whose duties carry the responsibility for the efficient utilization of all scales and standards of labor normally falling within the engineer's sphere of control.

It was, perhaps, this geographical spread in experience which first implanted in the author's mind a realization of the truly unique economic position occupied by the U.S.A. An observant individual with the industrial and agricultural map of the world before him cannot fail to appreciate the abundant natural resources with which nature has endowed the U.S.; these resources are readily accessible, and the climate is mostly benevolent. All that

has been needed has been the availability of a physically vigorous, mentally healthy population. Obviously, no alchemy has been needed wherewith to generate that which we term our wealth. Here hard-headed common sense, and a willingness not only to put the hand to the plow, but to keep it there, have always been the elements required, and to a major extent, provided.

The one great problem which exists today is the proper utilization of manpower, so that there may be preserved, and continually enhanced, a bountiful economy. Almighty God and our forefathers provided the land and the major tools of intelligence and physical strength wherewith to develop this country. The contribution which is demanded today is brainpower to be expended in the use of our quantity-limited manpower resources.

Whereas in varying degree most other countries in the world have an abundance of manpower and a shortage in natural resources, in the U.S. the exact opposite is the case. In many foreign countries the over-abundance of manpower makes its hiring price relatively cheap, as compared with the relatively high price accruing to American labor which is in relatively short supply.

In other words, economical manpower utilization is the problem of the day in the U.S.A. An acute shortage of manpower in many important fields is now evident. A workload characterized by the high technology of war materiel makes heavier demands than normal on the available skilled talent. The net of this is that henceforth the U.S. prospers or fails in the achievement of its objectives according to the quality of the management injected into the proper utilization of manpower resources. The author, at this point, strongly emphasizes the fact that this problem is not primarily in the bailiwick of the personnel manager, onto whom all too frequently the responsibilities are thrust; the problem lies squarely at the door of the managing engineer who assigns the work to his subordinates and who must see that these subordinates are properly trained in such a way that they can accept these work assignments with the fair assumption that they will turn out a satisfactory end product.

Profligacy in the use of manpower, during the world's periodic wars, has wrought nothing but disaster on those countries which have practiced it. History, ancient and modern, is replete with examples of the fall of nations which failed to realize that their manpower was their most valuable asset. The fact is patent that Britain and France, within the span of the last two major World Wars, have so dissipated and decimated the flower of their manhood, that today their will and power to produce vigorously has been impaired to the point where the bruised intellect, gasping and grasping for a palliative, has turned to Socialism, and in some cases, to Communism, hoping, therein, to find the remedy it seeks.

Without exception, historical records of these two great massacres show that the catastrophes were invariably traceable to inadequate leadership, which, in turn, resulted in frantic attempts to utilize untrained, or but partially trained manpower. While there are plenty of obvious cases where no amount of training would make a man into a leader, it is equally true that there are innumerable examples of the assumption of leadership which is not backed up by adequate training, and which almost inevitably has resulted in disaster to the people who chose or were compelled to follow such a leader.

The time has gone forever when the old saw, "at the threat of war, 10,000 men will spring to arms," has any useful meaning whatsoever. In the face of today's technology, 10,000 untrained men, or 10 million for that matter, are an unwieldy mob, ripe for the conqueror's sword.

THE BASIC PRINCIPLES

Principle number one. Trained manpower is mandatory. Without training, the physically strong can be made to yield to the comparative weakling who is trained. There is no effective substitute for ability to think and to operate in a trained way. Training is of the very essence. It is, in fact, the accumulated, condensed experience of generations of people and thousands of years. Without it, we can be made to yield to a numerically inferior, but better organized, people; therefore trained manpower is mandatory.

Principle number two. Foresight in planning the availability of enough time and enough money, wherein and wherewith to train the manpower to win and still live in an environment true to the American standard of living is mandatory. Militarily, dead men tell no tales, but those who survive the conflict do. The survivors naturally feel very strongly about it, especially those who forever lost their contemporary friends and male relatives in the two World Wars. The U.S. civilian force even when fully mobilized is small, numerically, in proportion to the vast areas of the United States. It is also small in proportion to the degree of leadership which this force must now exercise in world affairs. Only by careful selectivity and adequate training can our small civilian force, and even proportionately smaller military force, perform their assigned and inescapable tasks, hence the need for the exercise of foresight in the provision of time and money wherewith to finance this training.

Principle number three. Use our highly paid people sparingly. American labor commands the highest price per capita per hour of any body of labor in the world. The very smallness of the labor force has provided the incentive which has resulted in the evolution of many spectacular labor-saving devices which have taken the backbreaking toil out of the laborer's task. In terms of world competition, however, the hourly price of our labor is relatively very high, and unless this labor is used sparingly and with good judgment, the cost will be excessive to the point where the enterprise is bankrupted.

Principle number four. Exercise selectivity. For all tasks pick the best obtainable people, train them well, work them hard and pay them well. It is relatively easy to maintain high productivity and the minimum necessary industrial discipline, or for that matter, military discipline, with a carefully selected and well paid *minimum crew.*

Principle number five. Recognize that the trade unions are here to stay. If those few devoted dedicated men, handling the negotiations for the United Nations in Korea can see their job of generating an armistice through, why not we, when we have a much more placable kind of people to deal with. The trade unions can be much more wisely integrated into a solution of the overall U.S. manpower problem. To do this, it is necessary that we make use of their information and talents in a more intelligent way than that which has prevailed so far. These people, the members of the unions, know as well as we do, and certainly a Murray or a Lewis cannot fail to know, that to pull the trigger of the economic pistol, at a time when we face a bitter and implacable potential enemy (cold or hot war), can only result in a remarkably short time in the withdrawal, from the union leaders, of all their privileges, and ultimate condemnation under a Communist regime to the whipping post and the slave labor camp.

Principle number six. Economy in the use of manpower at the top is just as important, if not more important, than at any other location in the system.

Lately there have been restraining actions from the control points in Washington, to wit, Congress, the Bureau of the Budget, and the Manpower Division of the Secretary of Defense. Obviously these actions could only stem from a feeling of frustration, for they have resulted in the imposition of ceilings which makes it difficult to accomplish the assigned task under present conditions. The exercise of control through the imposition of manpower ceilings and limitations on the disposal of funds, all add up to an expression on the part of the powers-that-be that they feel the situation has gotten out of hand.

Congress incontrovertibly has tremendous resources in the way of information to draw on, and individually many of the members have a lot of valuable personal experience. Equally obviously, these powers-that-be demand more economy in the use of money, and this automatically means economy in the use of men, if for no other reason than that wages take about 90% of all money paid for services and goods.

Paradoxically Congress automatically sometimes denies itself that which it most diligently seeks, inasmuch as the Defense Act of 1947 has created a colossal pyramid of layers of reviewing authorities, each of which generates a terrific volume of work which only can be accomplished by copious manpower.

Complicated organizations, whether in industry or in government, just do not work economically, and a plea is in order for a program of simplification. It is presumable that Congress would go along. Congress wants the end result, i.e., economy.

To quote an industrial counterpart experience—our largest railroad is operated by a President, who is also the General Manager, who makes his daily decisions on five routine, brief, but absolutely accurate, daily reports. All really important decisions are based on these five reports, and the practice results in economy in the use of men and money at the top echelon.

Principle number seven. Good business organization demands well defined areas of responsibility delegated to all heads of departments. In a great many of the Defense Department offices in Washington, a superior operational performance could be forthcoming, if delegated to a civilian exercising loyal adherence to the policy of the Chief of the Department. Military interpretations are a strictly professional military matter necessarily always under the cognizance of the responsible military authority. This is a wide and adequate field for the officers of the various services to operate in. When, by accident or design, an officer takes over his chief civilian's duties, he renders everyone, including his country, a disservice, unless such a move be made only on a purely emergency basis.

In most respects, the U.S. Civil Service is an excellent and efficient organization, but there are a few vital areas in its make-up where it defeats efficiency in the utilization of manpower, i.e., a sure fire support for a raise in pay is a statement that a supervisor directs a bigger crew. The author, in sixteen years of firsthand experience, has never heard of a man obtaining a raise for the accomplishment of his regular assignment with a smaller crew. A premium paid out on this latter basis (such as prevails in most industrial establishments) could work many benefits.

As in all large organizations, our combined military and civil service system tends to overwork the good men and offers many loopholes for the escape of productiveness and responsibility on the part of those who seek to avoid these two necessary virtues.

The remedy, which obviously takes time to apply, lies in the delegation of a greater degree of personal responsibility to a small crew of permanent top civilian administrators of the highest pro-

fessional caliber, and collaterally this entails the payment to these top administrators of a rate of remuneration which is fairly competitive with that which goes with similar services performed in industry. An advantage which would inevitably accrue from the following of such a policy would be the freeing of the military from a great many of their present administrative duties, which preferably, in the interest of policy continuity, should be handled by top grade civilians.

Principle number eight. Conservation of skilled labor in peacetime. The last, and in the author's opinion one of the most important points, relates to the conservation of our highly skilled, highly specialized labor, in *peacetime*. The men who know how to make armor, guns, radar, tanks and submarines are frequently and shortsightedly dismissed in peacetime. This policy is utter folly, and could easily amount to a form of national suicide. The unperceptive reductions in force brought about in the Government workshops in 1948 and 1949 is a case in point. It is a conservative estimate of the situation to point out that the loss of essential skills, brought about by that move, has cost the U.S. many millions of dollars in actual cash, and contributed in a major way to the months and months of delay in the consummation of our rearmament program; all of the foregoing occurring at a time when competing forces abroad are building up their war potential at an extremely rapid rate.

SUMMARY

In conclusion, the eight basic principles advocated are:

1. Well *trained* manpower is mandatory.
2. Adequate *money* and *time* are essential for adequate training.
3. Well trained people command a high rate of pay so we must use the *fewest people* to gain our ends.
4. For all tasks select good manpower material, train them, work them hard, and *pay them well.*
5. Put the *unions* to work in the common cause.
6. Economy in the use of manpower in the *top* echelon is of *prime* importance.
7. Good business organization *demands* well defined areas of responsibility. Do not over-reach into the other person's area of responsibility.
8. *Conserve* our skilled labor in *peacetime.* It takes years to build it up, and our productive economy is such that much of it is irreplacable.

RECOMMENDED PRACTICE FOR THE WELDING OF STEEL CASTINGS

ACKNOWLEDGMENT

This article is an excerpt of the report of an exhaustive study of welding practices for the welding of steel castings, carried out as a part of the continuing research and development program of Steel Founders' Society of America. It was published in the April 1952 issue of "The Welding Journal."

INTRODUCTION

Welding is an inmportant part of the manufacturing of steel castings. It is used in two ways—for the repair of defects incident to the manufacture of castings, and in the fabrication of composite structures. This report deals only with the welding of steel castings by the metal-arc method.

Arc-welding procedures in the foundry are a result of many years of experience, and are in line with accepted welding practice. However, the increase in variety of castings manufactured, and of electrodes available, has made it necessary to revise some of the procedures. To do this, experience with wrought steels (where welding has been used far more extensively) has been drawn upon. Steel castings can be welded as readily as wrought steels, so that the extensive information gathered on wrought steels can be applied to the welding of steel castings.

In some ways, welding of castings is simpler than welding wrought steels, because, with relatively few exceptions, all castings welded are subsequently stress relieved, or given a full heat treatment (e.g., normalized, or quenched and tempered). This eliminates two of the principal drawbacks found in some welded wrought steels—excessive hardness next to the weld, and severe weld stresses.

The primary objective of this report is to recommend procedures which will lead to sound, crack-free welds. With the many possible combinations of castings and electrodes, it is recognized that there may be other welding procedures equally as satisfactory as those recommended. Also, there are times when it is neither necessary nor economical to make welds of the highest quality. Such exceptions will not be considered in this report. They have to be made on the spot, for a particular job.

Specifications for Welding Castings

It is not an objective of this report to discuss in any detail the various specifications for the welding of steel castings. There are four general types of such specifications: issued by government agencies, such as the Navy, Army and Air Force; by technical societies, such as the American Welding Society,

American Society for Testing Materials and the Association of American Railroads; by various foundries, for governing welding procedures in their own plants; and by industrial customers of the foundries. In many cases, particularly in government specifications, the welding procedures are merely a part of a broader specification for some one type of casting. This is also true of some of the technical society specifications.

A number of the government and technical society specifications have been reviewed for the purpose of checking the procedures recommended in this report against the procedures required by the various specifications. Generally, the specified procedures are less concise than the present recommended procedures, so that good comparisons were not possible.

Casting Defects That Can Be Repaired by Welding

The casting defects that can be repaired by welding are well known to the foundries and have been described in the foundry literature. It is outside the scope of this report to describe these defects, or to distinguish between those which should be repaired by welding and those which should not, because of their size or location.

Some casting specifications arbitrarily classify defects into major and minor ones, according to the relative dimensions of the defects and the castings, or according to the reason for making the weld. Such classifications have not been considered in this report. Actually, welding small defects frequently requires greater care than welding large ones. This will be explained later.

PREPARATION FOR WELDING

The methods for removing defects in castings are well known to the foundry industry and need not be described in detail here. They include pressure blasting, chipping (with a pneumatic or hand chisel), grinding and flame gouging. Within reasonable limits, the first three may be done regardless of the temperature of the casting. Flame gouging, at least for the higher composition castings, must be done only when the casting is preheated. Otherwise, checks or cracks may be produced at the surface.

To properly prepare a casting for repair welding, all traces of the defect must be removed. For deep cracks this is sometimes difficult, because the method used for removing the defect may cause the metal to flow over the cracks. In such cases, careful inspection such as magnetic particle testing, deep acid etching, etc., is needed to determine whether the defect is entirely removed.

The shape of the groove made in removing a defect or preparing two castings for fabrication is also important. The dimensions of the groove are largely controlled by the size of the defect or the casting section to be welded. All changes in contour should be fairly gradual, and all sides should slope toward the bottom of the groove. Sharp inside corners serve as points of stress concentration, which might start cracks during welding. Deep, narrow grooves make it very difficult to get complete weld penetration. They promote undercutting. Incomplete penetration and undercutting may lead to slag inclusions or cavities at the roots and sidewalls of the welds. In some cases, such weld defects would require removal of the weld, recleaning of the groove surfaces and rewelding.

Sometimes, two defects may be so close to each other that one of them may not be discovered during inspection. The one that is found may be completely removed, and a clean repair groove

made. Then, the repair weld may penetrate through the sound metal between the two defects, and expose the second one. When this happens, welding should be stopped and the second defect completely removed.

When defects extend entirely through a casting, it is best to turn it over and lay one or more sealing passes from the root side of the repair weld. If this cannot be done, a backing should be used whenever possible. Backings can be made from refractory materials available in the foundry, such as firebrick, silica brick, mullite brick, magnesite or carbon plates. These should be thoroughly dried, because if water vapor is produced during welding, it may cause cold cracking at the joint, as explained later. Metals, such as copper, plain-carbon steel or stainless steel, may also be used as backing material. Ordinarily, the back-up material merely acts as a dam and is not bonded to the weld metal. Such is the case with refractories and copper. Backings forming integral parts of the castings should generally have the same composition. Where pickup of backing metal is not wanted, it is possible to cover the backings with washes of refractory materials.

EFFECTS OF WELDING

The peak temperature in metal-arc welding is highly localized, so that there is a sharp temperature gradient between the molten weld metal and the base metal only a fraction of an inch away. The rapid cooling of this weld zone by the adjacent unaffected base metal causes a wide variety of structures within this narrow zone. The structural changes involved have been described many times in the welding literature. Good descriptions are given in the Welding Handbook (A.W.S.),[1] and in Welding Metallurgy (A.W.S.).[2] The principal effects of welding castings and the subsequent rapid cooling are quench hardness, thermal stresses, hot cracks and cold cracks—i.e., cracks formed well below the critical temperature.

Quench Hardness

The rapid cooling of the high-temperature zone of the base metal next to the weld quench-hardens that zone. Just as in ordinary heat treating, the maximum hardness in the weld heat-affected zone depends primarily on the carbon content of the casting. The maximum hardness may be increased somewhat by other elements, but their primary effect is to promote the retention of austenite by making its transformation more sluggish.

In the past, it was thought that hardness was directly related to underbead cracking, because underbead cracking was always found in zones of high hardness. It has recently been shown that this is not the whole story, and that factors other than hardness are necessary to produce underbead cracking. When free from cracks, the principal drawback of a hardened heat-affected zone is that it makes machining difficult.

Weld metal, too, particularly the earlier passes in multipass welds, is rapidly cooled by the quenching action of the unaffected base metal. It also is quench-hardened to a certain degree. However, its carbon content is generally quite low, and the amount of hardening is also low.

Fortunately, most castings with either repair or construction welds are at least stress relieved after welding. This eliminates detrimental hardness in the heat-affected zone.

Thermal Stresses

The rapid heating and cooling of the weld produce thermal stresses which may be quite large. During heating, there is a rapid expansion of the base metal around the weld. If the unaffected metal surrounding the weld zone is

strong enough, or if the casting is rigidly clamped, the expanding metal in the weld zone will be upset. Upon cooling, the upset section will not return to its original dimensions, and internal stresses will be set up. Shrinkage of the solidified weld metal will also cause internal stresses.

If internal stresses in welded castings are high enough, they may cause hot cracks, or permanent distortion, and may propagate cold cracks. Unless they do produce one or more of these defects, internal weld stresses are not serious. They are essentially eliminated by any of the heat treatments ordinarily given castings after welding.

Hot Cracking

Hot cracking occurs while the heat-affected base metal or the solidified weld metal is still at such high temperature that it is unable to withstand even relatively low internal stresses. If stress is developed while the metal is in this weak condition, it tears instead of deforming, as it would at a slightly lower temperature.

In the casting being considered, hot cracks are more apt to occur in the weld metal than in the base metal. One reason for this is that the weld metal is hotter than the base metal and cools last. Also, because of directional freezing, weld metal has columnar grains. This structure is generally weaker than the equiaxed grains of castings.

Cold Crackings

The term cold cracking, i.e., cracking occurring at temperatures well below the critical temperature, has until very recently been applied exclusively to underbead cracking of the base metal in the heat-affected zone. Underbead cracking is caused by a combination of the structure formed by the high cooling rate in the high-temperature portion of the heat-affected zone, hydrogen from the arc atmosphere, and internal stresses.

Hydrogen is present in most arc atmospheres, though the amount varies greatly with different electrode coatings. During welding, hydrogen is dissolved by the austenite in the hot base metal adjacent to the weld. If the base metal cools rapidly enough to retain some austenite, there will be dissolved hydrogen concentrated in the austenite. When the austenite, which is unstable at ordinary temperatures, finally transforms, it releases the hydrogen. This forms in microscopic or submicroscopic voids in the base metal under very high aerostatic pressures. These pressures frequently start cracks, which are then propagated by the thermal stresses in the weld zone.

At least one investigation[3] has shown that steel castings are less prone to underbead cracking than wrought steels of similar composition. This investigation was limited to carbon-manganese steels, so it is not known whether this is a characteristic of other types of cast and wrought steels.

Recent work by Flanigan[4] and Bland[5] indicates that weld metal also may be prone to cold cracking. They have shown that even the ductilities of low-carbon weld metals may be lowered by quenching. Microfissures have been found in weld metals so treated. Ductilities are not affected when preheats over about 300°F. are used. Low ductilities may be improved by postheating to temperatures around 600°F. It is thought that hydrogen may be the cause of the lowering of ductility in these weld metals, but this has not definitely been established.

When preheated or postheated, it is unlikely that the ductilities of welds in steel castings would be seriously affected by the cooling rates.

Porosity

Another serious defect sometimes encountered in welding is weld-metal porosity. This is caused by entrapped gases. Gases may come from the arc atmosphere, either by the breakdown of

gas-forming components, particularly carbohydrates, or by decomposition of moisture picked up by the electrodes during storage. Gases may also be formed by reaction of elements in the base metal at welding temperatures. Sulphur is one of the leading porosity-forming elements. Weld-metal porosity may also be caused by welding over porous base metal, or by welding through sand pockets in the base metal.

Porosity can be minimized by slowing down the freezing of the molten weld metal. This allows the gases coming out of solution to escape to the surface of the weld metal. Where severe porosity is found, the weld should be chipped out, and the groove rewelded.

COMBATING THE EFFECTS OF WELDING

The preceding sections have shown that, while there are a number of undesirable effects of welding, only four are found in repair welds of castings. These are, in the order of probable importance, cold cracking, hot cracking, permanent deformation and weld-metal porosity. Undercut and notches caused by improper fusion may also be found. They are the result of poor workmanship, not effects of welding *per se* so are not included in the preceding list. For the castings considered in this report it should be possible to minimize all four of these effects. The most effective step in the procedure for doing this is to slow down the heating and cooling rates of the weld metal and weld heat-affected zone. This is done by selection of suitable preheating and interpass temperatures, and postwelding heat treatments.

Preheat

Preheat reduces the temperature differential between the weld and the unaffected base metal. Chances of upsetting the heat-affected base metal by thermal expansion are thus decreased, but the principal benefits of preheating are those resulting from slower cooling of the weld zone, particularly at low temperatures in the range of martensite formation. Slow cooling promotes completion of austenitic transformation at higher temperatures in this range. This in turn eliminates the principal cause of underbead cracking. Slow cooling rates also lessen the chances of hot cracking, and lower the internal stresses set up during cooling.

Two types of preheat are used—general, in which the entire casting is heated, usually in a furnace; and local, where only a section around the weld is heated, usually by a gas torch or electric-resistance heaters. The former is always preferable, as it minimizes localized stresses. In foundries, furnaces for general preheating are at hand.

The preheat temperature depends on the properties of the casting and weld metal, and on the size and shape of the casting. There are certain general rules to follow in selecting the correct preheat temperature. In the first place, it should be as low as practically possible. This is because, with increasing temperature, it is more difficult to lay a weld bead without undercut, and protection for the welding operator becomes a problem. While the use of the minimum preheating temperature is desirable for the above reasons, a temperature of 50 to 100°F. above the minimum will seldom do any harm and, therefore, close calculation of the preheat temperature does not seem necessary. However, a good rule to apply when in doubt as to preheating would be always to preheat, or preheat at a little higher temperature.

The chemical composition of the casting is one major factor in selecting preheat. Steels low in carbon and alloy contents do not tend to quench harden successively nor to form cold cracks. They require either no preheat, or much less preheat than needed for a

high-carbon, high-alloy casting. This reasoning also applies to the deposited weld metal, particularly in multipass welds. In general, plain-carbon and low-alloy castings with carbon contents below 0.30% would not require preheat. For castings with carbon contents between 0.30 and 0.50%, preheats of 200 to 400°F. should be used. The higher side of this range would be used with the higher carbon and alloy contents, and increasing thickness and complexity of the casting. In some cases, where both the carbon and alloy contents are high, preheats over 400°F. may be necessary.

Thickness and shape of the casting also must be considered. Thicker castings have greater heat-absorbing capacities, and, therefore, in effect, greater quenching powers. As a rule, the thicker the casting (provided it needs preheat at all), the higher the preheat should be. Simple shapes with fairly uniform cross sections will cool uniformly, and require a minimum of preheat. Complex castings consisting of alternating thin and thick sections will cool more rapidly in the thin sections, which may lead to severe internal stresses. In such a case, a higher preheat should be used than for a more uniform shape. Also, they should be protected from drafts during welding, and should be cooled more slowly than less complex castings of the same composition.

Another factor influencing the selection of a preheating temperature is the size of the defect in relation to the thickness of the casting. A small weld cools more rapidly than a large one.

Thus, tack welding on a sensitive steel can be a dangerous procedure and casting failure has resulted from cracks started from a tack weld made without preheat.

In order to obtain the correct preheating temperature, furnaces with accurate controls can be used. When these are not available, Tempilstiks, which leave a mark that melts when the part reaches the required temperature, can be obtained for a wide range of temperatures within the normal preheating temperature range. Surface pyrometers are also available and very useful.

Interpass Temperature

The interpass temperature, i.e., the temperature between passes in multipass welds, should be considered along with preheat. In order to maintain the desirable conditions developed by preheat, the interpass temperature should never be below the preheat temperature. The interpass temperature can safely exceed the preheat temperature by 100 to 200° F., depending on the particular casting, and frequently does. The interpass temperature should not be allowed to go so high that the side walls of the weld groove will be severely undercut.

For rangy castings, the welding heat may not be enough to maintain the preheat temperature. In this case, additional heat is suppied by reheating the entire casting or locally heating the weld area.

THE WELDING OPERATIONS

After the preheating and interpass heating stages, the next stage in the welding procedure, where some correction of the effects of welding heat may be done, is the welding operation itself.

Choice of Electrode

Choice of electrode is one of the important steps in the procedure for welding a casting or several castings together. The arc atmospheres produced by different types and sizes of electrodes can affect the quality of a weld and the ease of welding.

Arc Atmosphere.—It has already been mentioned that different arc atmospheres contain varying amounts of

hydrogen, and that the amount of hydrogen depends on the composition of the coating. This varies for the different types of electrodes [which are discussed in detail in the complete S.F.S.A. manual from which this material is excerpted]. It is sufficient here to say that, by selecting types which will have arc atmospheres low in hydrogen, the chances for underbead cracking in the weld heat-affected zone will be minimized.

Heat Input.—Some classes of electrodes require higher welding currents for a given diameter than others, and, consequently, have higher burn-off rates, i.e., deposit more metal in a given time. Also, larger diameter electrodes of a given class require more current than smaller ones. Increasing the current increases the welding heat input. This acts, to a lesser degree, like preheating, flattening out the temperature differential in the weld area, and lowering the cooling rate. Therefore, other things being equal (which they frequently are not), the "hotter," larger diameter electrodes should be selected for repair welding.

Welding Current

The welding current used with a certain size of electrode may also be varied somewhat, when welding in a given position, e.g., downhand. It usually has to be varied for welding in other positions, e.g., vertical.

Manufacturers usually print the recommended current ranges for their electrodes on the containers. These ranges will vary somewhat even for electrodes of the same class. Usually the ranges are rather wide. The higher currents are for downhand welding under favorable conditions. Those on the lower side are for situations where careful control of the weld metal is needed, such as in vertical or overhead welding, or where the preheat is high.

Experienced welders can select the proper current. Some will tend, however, to use higher currents than they should in order to get out more work. Poor welds may result, if this is allowed.

In Table 1, typical current ranges are given for three commonly used sizes of electrodes for plain-carbon and low-alloy steel castings.

As already mentioned, higher welding currents will give higher welding heat inputs, which are frequently advantageous. However, for making a good weld with a given size and type of electrode, in a given position, the variation in welding current cannot be too great.

TABLE 1—TYPICAL CURRENT AND ARC-VOLTAGE RANGES FOR MILD AND LOW-ALLOY STEEL ELECTRODES*

A.W.S.-A.S.T.M. electrode class	*Electrode diameter,* ⅛ *in.*		3/16 *in.*		¼ *in.*	
	Amp.	*Arc volts*	*Amp.*	*Arc volts*	*Amp.*	*Arc volts*
EXX10 and EXX11†	80-120	24-26	140-220	26-30	200-300	28-32
E6012	80-130	18-22	140-250	20-24	200-400	20-24
EXX13	70-120	18-22	140-240	20-24	200-350	22-26
EXX15 and EXX16	100-150	20-22	160-240	22-24	300-375	24-27
EXX20 and EXX30	100-140	24-28	175-250	30-36	250-400	30-36

* From the *Welding Handbook*, AWS, Table 1, p. 846.

† The symbols "X" are used to represent a group of related electrode classes. For example, EXX10 represents Classes E6010, E7010, E8010, etc., while E60XX would represent Classes E6010, E6011, E6012, etc.

Deposition Technique

There are many ways of depositing a weld bead in a groove. Usually, there are two ways that are best for certain welding jobs. Their selection depends on the size of the groove, the thickness of the casting section and the properties of the casting and weld metal. The position that the weld is to be made in must also be considered, as the deposition technique for position welding is different than that for down-hand welding. However, position welding for castings repair is so rare that it can be neglected in this discussion.

There are two basic factors that have to be considered in selecting the proper deposition technique. These are the speed of welding and the volume of the weld. These two factors may be varied to help control welding heat effects. For a given size of weld bead, the higher the welding speed, the more rapid the cooling rate. This increases the underbead hardness and tendency to underbead cracking. On the other hand, it reduces the tendency to distortion by minimizing the volume of heat-affected base metal. The effects of slower speeds are the converse. When preheat is used, welding speed—provided a sound, well-contoured bead is laid—is not important.

The effects of volume of the weld are quite similar to those of speed, a small weld producing effects quite similar to those with high speed, because, again, the cooling rate of the weld zone is relatively fast. Conversely, a large volume of weld metal deposited in a single pass results in considerably more heat in the weld zone. This gives a slower rate of cooling in the weld zone, but higher shrinkage stresses. Of course, unless the shrinkage stresses are sufficiently high to cause cracking in the weld metal or base metal, they are of no particular importance in repair welds, where the castings will usually be at least stress relieved after welding.

There are two main types of weld beads, the string bead and the weave bead. The string bead is laid in a continuous pass in one direction. The weave bead also progresses in one direction, but also has a side-to-side motion. There are many patterns of weave bead, including figure eights, elipses, etc. A modification of the weaving technique which can be used with many of the weave patterns is whipping. This is used to control the molten weld pool by removing the arc heat, while still maintaining the arc.

String and weave beads are used in single layers, when the groove can be filled in a single pass. Where the groove is too deep or too wide for it to be filled in one pass, multiple layers are used. These may be laid with either string or weave beads, or a combination of the two.

Still another way of controlling the welding heat effects by deposition technique is the welding sequence. This can be varied even in single-layer welds. The most common sequence for single-layer welds is simple string or weave beads laid in one direction. These are started at one end of the weld and continued to the other. Where the weld is long, several electrodes may be used. In this case, the beads are laid one after the other in the same direction. In long welds where it may be desirable to minimize longitudinal and transverse weld shrinkage effects, the back-step method can be used. In this procedure, short length, say 2 to 4 in., are deposited.

In multiple-layer welding, there is still a greater variety of sequences that may be used. Again, string or weave beads laid in one direction are most commonly used. The step-back sequence can also be used, either as string beads or weave beads. Two other sequences designed primarily to minimize shrinkage in fairly large groove welds are the block sequence and the cascade sequence. In the block sequence, the weld is built up by intermittent blocks which are subsequently joined by other blocks after the first group is completed. The chief

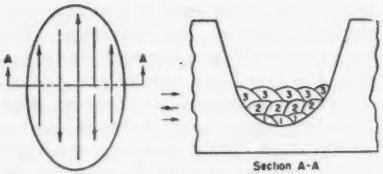

Fig. 1. — *Horizontal-layer deposition*

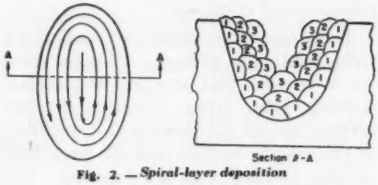

Fig. 2. — *Spiral-layer deposition*

benefit of the block sequence is to minimize longitudinal weld stresses. It does not have much effect on transverse shrinkage, except as the stresses in the lower passes are relieved by the welding heat from succeeding passes. The cascade sequence reduces both transverse and longitudinal shrinkage stresses as the weld progresses, particularly when used with a weaving bead. By using it, the heat from the first half of any bead will tend to temper or stress relieve the last half of the bead immediately before it. The net result is that all segments of the first-pass bead are stress relieved by the next succeeding increment so that no major locked-up stresses can remain. Both of these methods require more welding time than ordinary multilayer welds. They should not be used, except where the greater reduction of stress warrants it. Preheating would largely eliminate need for such special techniques.

For the multilayer welding of large grooves, any one of the deposition techniques discussed can be used. Sometimes, as a matter of convenience, it is simplest to run one bead in one direction and the next bead in the opposite direction. In general, the simplest procedure is to build up the weld in horizontal layers, such as illustrated in Fig. 1. It has been claimed[6] that the least stress is produced when the weld can be built up in spiral layers around the side, as shown in Fig. 2.

Nearly all repair welds in castings can be made with string or weave beads laid from start to finish in single or multiple layers.

In the section on preparation for welding, the use of backings was discussed. In general, the presence of a backing does not markedly change the required deposition technique. However, particular care must be taken in laying the root passes. Where a backing is to become a part of the assembly, it is very important to see that full penetration into the backing is obtained. Where a temporary backing, either ceramic or ceramic-washed metal, is used, particular care should be taken to insure good fusion between the root pass and the side walls of the groove. If this is not done and there is lack of fusion between the root pass and the side walls, the unfused sections will act as stress raisers. Stress raisers naturally increase the possibility of cracking.

Another step in deposition technique which can be extremely important is arc length. Ordinarily, a good welder automatically holds a proper, or "normal" arc length. For the low-hydrogen type electrodes—AWS-ASTM Classes EXX15 and EXX16—the arc required for depositing high-quality weld metal is shorter than for other classes of electrodes. This is an important difference which may be overlooked even by good welders, whose experience has been with the other classes of electrodes. They should be frequently reminded of this difference, until they have become thoroughly familiar with the low-hydrogen electrodes.

Good deposition technique, though important, is generally not too difficult to choose. Competent operators may not all use the same technique—in fact, they

almost certainly will not—but with relatively little guidance, they will choose one that will do the job satisfactorily.

Peening

Distortion is sometimes minimized by peening the weld. Heavy peening after each pass will reduce distortion by "spreading out" the weld metal, thus counterbalancing its natural shrinkage. For castings thick enough to resist distortion, deep peening gives a mechanical stress relief. Peening must be carefully controlled, because overpeening causes weld-metal cracking, and is, therefore, worse than none. The permissible amount of peening is somewhat dependent on the mass of the casting, heavier peening forces being required for heavier castings.

For castings which are to be at least stress relieved after welding, peening would generally not be used. Where severe distortion during welding might occur, for example, in filling a relatively large groove in a thin rangy casting, peening may be helpful in minimizing distortion.

Postwelding Heat Treatment

The great majority of castings can be cooled to room temperature in still air after welding, but those of higher composition, which are more sensitive to cracking, should have retarded cooling from the welding temperature. This is primarily to give greater insurance against cold cracking. Such retarded cooling may be accomplished by heating with a flame or burying the casting in some insulating material. However, inasmuch as crack-sensitive steels require preheating as well, one of the best practices is to put the castings back in the preheating furnace as soon as welded.

All welded castings except some of the low-carbon unalloyed steels should be given a postwelding heat treatment. The minimum treatment should be a stress relief, which consists of heating to 1100 to 1250°F. Such a treatment will remove practically all residual stresses and prevent any subsequent cold cracking, but most important, it will reduce the hardness of the heat-affected zone to the point where machining or chipping will present no problem.

Many castings will be given their regular final heat treatment, such as normalizing or quenching and tempering. Either of these treatments will eliminate the heat-affected zone and, of course, make the stress-relieving treatment unnecessary. Though normalizing or quenching and tempering generally improves the base metal, they may reduce the weld metal properties, unless suitable electrodes are chosen.

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EXPLOSIONS IN ENCLOSED CRANKCASES

ACKNOWLEDGMENT

This article is an abridged version of a paper by JOHN LAMB, Head of The Marine Research and Development Department of the Anglo-Saxon Petroleum Co., Ltd. The paper was presented at a meeting of The Institution of Mechanical Engineers held in London on 25 April, 1952. The abridged version was published in the May 1952 issue of "The British Motor Ship."

Prevention of crankcase explosions resolves itself into two problems, the first being prevention of the formation of an explosive mixture, and the second elimination of the means of igniting the mixture. Solution of either would effectively remove the possibility of an explosion.

As regards the former, if a crankcase were filled and kept charged with inert gas an explosion could not occur. Exhaust gases of oil engines could be used for this purpose. Chemists state that if the inert gas content could be maintained at 30 percent or over, a crankcase would be in a safe condition, but the author thinks that to ensure that would be difficult.

Whilst carbon dioxide would not adversely affect the condition of lubricating oil unless sea water were present, there can be no doubt about the ultimate condition of the oil if exhaust gases were led into the crankcase.

Some of the minor explosions occur after an engine has been stopped and a crankcase door has been opened for inspection purposes. In such instances, even though some part of the engine was hot enough to ignite the oil mist, it would seem that ignition was delayed until additional air entered through the open door.

The practice of ventilating crankcases by a current of air has many adherents, but the fact that explosions have occurred in engines so treated is sufficient proof that it does not ensure immunity. Constant changing of a portion of the gaseous contents in this way will reduce the density of the mist, and may reduce the violence of an explosion, but it is highly improbable that ventilation within practical limits would put every part of the crankcase in a safe condition.

It is doubtful whether hermetically sealed crankcases would achieve the desired result, for the reason that a crankcase is full of air before the engine is started, and observations have shown that, even after weeks of continuous operation, air forms a large proportion of the gaseous contents.

The author considers, therefore, that it is not practicable to make enclosed crankcases safe by ventilation, and it is not possible to do so by hermetic sealing.

Generally, when bearings overheat the heating process is at first gradual, and

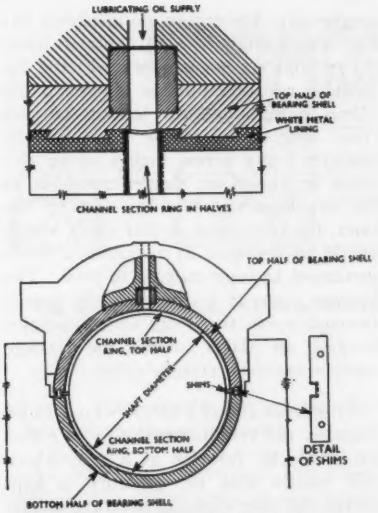

Fig. 1. — Crankshaft bearing. Proposed method of preventing molten white metal running into the oil supply hole.

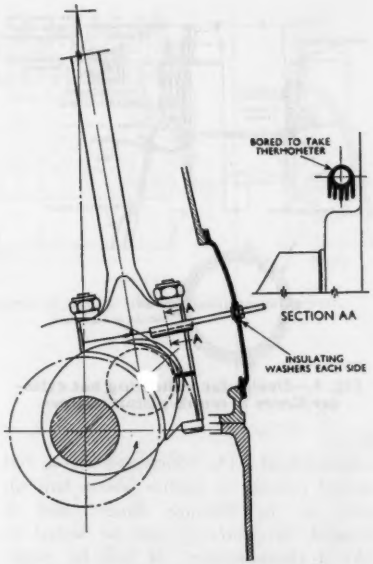

Fig. 2.—Method of detecting temperature increase in crankpin bearings.

if detected in time the engine can be stopped before a bearing becomes sufficiently hot to damage the anti-friction metal. When a temperature of about 500 degrees F. is reached the anti-friction metal melts, and may run into the oil hole.

A simple method of preventing oil holes from becoming choked in this way is shown in Fig. 1. This shows the usual annular oil groove lined by a channel-shaped ring split in halves, made of a material such as copper, which has a relatively high melting point and will not damage the surface of the revolving steel crankpin or shaft journal.

Prevention of Hot Pistons.—The pistons of modern crosshead engines seldom run hot and, so far as the author is aware, have never been the cause of a crankcase explosion. Trunk pistons, however, become hot as a result of either insufficient working clearance or inefficient lubrication. Piston blow-past could result in inefficient lubrication and subsequent overheating.

Gauging Pistons and Liners for Distortion.—The author's method of checking for distortion of pistons is to provide a cast-iron ring gauge 6 ins. deep and 2 ins. thick and having suitable means for handling. After being annealed, the internal diameter of the ring is machined to two thousandths of an inch above the drawing size of the largest part of the piston. For cylinder liners, a plug gauge 6 ins. deep is provided, the external diameter being machined, after annealing, to two thousandths of an inch below the original cylinder bore.

A method of detecting temperature rise in crankpin bearings, which is not dependent upon the oil, is to insert, and firmly secure, in the position shown in Fig. 2, rods made of pure aluminum or copper, which readily absorb and

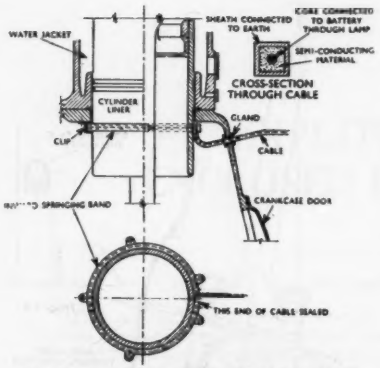

Fig. 3.—Device for indicating hot cylinder liners of trunk-piston engines.

conduct heat. The inner end of the rod should extend to within about half an inch of the bearing flange, and if thought necessary it can be bored to take a thermometer. It will be found possible, however, to detect a 20-degree F. rise in temperature by touching the projecting end with the hand.

Early detection of temperature rise in crosshead bearings is not easy unless small doors are provided near the top of the crankcase. It is even more difficult with gudgeon bearings and, unfortunately, such bearings are not infrequently responsible for pistons becoming hot. The author cannot at the present time suggest a practical method of detecting overheating of such bearings.

Hot-piston Indicator.—Most crankcase explosions that have occurred in trunk-piston engines were due to hot pistons, which are totally inaccessible while the engine is running. Generally, the cylinder liner, which is subsequently affected, is also inaccessible, so that an aid is particularly necessary to indicate a temperature rise in pistons.

The layout of such a device fitted to one of the trunk-piston engines in the *Auris* is shown in Fig. 3. The detecting elements consist of lengths of single-core, mineral-oxide-insulated cable, which encircle each cylinder liner. At normal engine temperatures the insulation resistance of the mineral oxide filling is high and the leakage current from core to sheath is low. Should, however, only a few inches of an element be raised in temperature due to the development of a hot spot on the liner, the insulation of that short length would so decrease as to allow a much increased leakage current to flow. The leakage current is continuously passed through a sensitive relay which operates to give an alarm, should the leakage current exceed a certain value.

Crankcase Relief Valves.—To prevent damage, the requirements are (1) that the gases be released at a rate which will ensure that the pressure is kept within the safe working pressure of any part of the crankcase, and (2) that immediately the excess pressure has been released the escape opening be instantly closed to prevent entry of air, and a second explosion.

On occasions, an explosion has been immediately followed by another, sometimes of greater violence. This is attributed to the partial vacuum created by the momentum of the released gases causing air to rush into the crankcase and mix with the remaining oil mist. During the tests described later, a colored film strip of explosions caused in this way was obtained.

The author's most recent experience of a crankcase explosion occurred in an engine crankcase, the construction of which is shown in Fig. 4. This follows normal practice. The only communication with the atmosphere was through a vent pipe of 2 ins. diameter.

The first explosion was caused by the overheating of No. 2 piston. The cover, indicated at the opposite end of the engine, was broken into several pieces and projected with great force about the engine-room. The engine had been

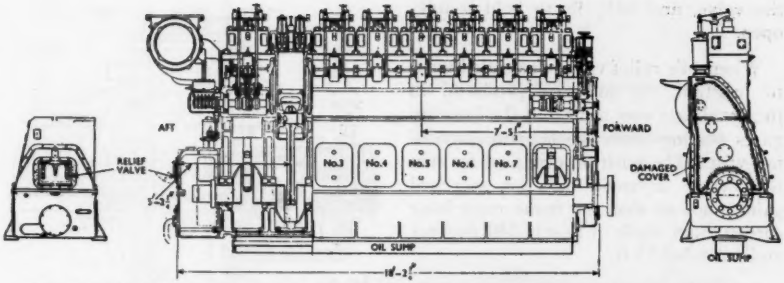

Fig. 4.—A 1,005 b.h.p. engine in the crankcase of which two explosions occurred.

running continuously for several days when the explosion occurred.

An interesting feature of this explosion is that other parts of the crankcase, nearer to No. 2 piston, showed no sign of strain. This supports the theory that the pressure produced at the seat of the explosion is relatively small, and that the farther the pressure-waves travel through oily mist, the greater will be the accumulated pressure.

The steps taken to prevent a repetition of this damage included the fitting of a spring-loaded hinge valve as indicated in Fig. 4.

About two years later a second explosion occurred. This was caused by the running hot of No. 5 piston, which is situated about mid-length. Both ends of the crankcase would, therefore, have been subjected to approximately the same pressure.

This eight-cylinder engine has a total crankcase volume of 220 cu. ft. and a crankcase volume per cylinder of approximately 28 cu. ft. The area of the pressure-release opening is 118 sq. ins., so that the ratio of release area to total crankcase volume is 1 sq. in. per 1.8 cu. ft., which in this particular instance proved sufficient to prevent damage to the engine.

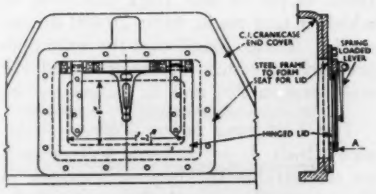

Fig. 5.—Spring-loaded hinged valve for releasing excess pressure in crankcases.

The advantages of the form of relief valve in Fig. 5 are that it is simple in construction and that when fully open it offers minimum resistance to the flow of excess gases. The disadvantages are that if the spring load is sufficient to ensure the closing of the door with the speed necessary to prevent air entering the crankcase, the load may be too great to ensure its opening with the speed necessary to prevent a serious build-up of pressure.

In the case just quoted the spring load holding the relief valve in closed position was just sufficient to avoid movement and leakages of mist resulting from the pulsation of the eight trunk pistons. When it was tested by means of a sensitive spring-balance a pressure of 4 lb., applied at the point indicated by A (Fig. 5), was found to be required to "crack"

the valve, and 13¾ lb. to hold it fully open.

When this relief valve was called upon to function, the pressure produced in the crankcase was such that the burning gases issuing from the aperture spread fan-wise. The position occupied by men who were injured, and the scorched paint, showed that the flame must have spread to an angle of nearly 180 degrees and extended 15 ft.

A rough estimate may be made of the minimum pressure that would be required to shatter the crankcase end-cover. Assuming the tensile breaking stress of the 10 mm. thick cast iron, of which it was made, to be 20,000 lb. per sq. in., it was found that the minimum pressure at which the cover would fail was between 7½ and 12 lb. per sq. in.

The Lightning Safety Valve.—A device which, it is claimed, will prevent an undesirable build-up of pressure in the event of an explosion and, at the same time, close instantly is shown in Fig. 6. This device is called the Lightning safety valve, and has in slightly different form been used with good effect for many years in connection with the starting-air systems of marine Diesel engines.

Special features of this valve are that it:

(1) Can be designed to open at any predetermined pressure above atmospheric;

(2) Opens instantly and to its fullest extent without shock when the predetermined pressure is reached.

(3) Closes immediately the excess pressure is released.

The main advantage of this valve over spring-loaded relief valves is that whereas in the latter the load is progressively increased as the valve opens, the load on the Lightning valve is decreased. Actually, at the moment the valve begins to open, about 90 percent of the load is thrown off and it opens instantly to its fullest extent.

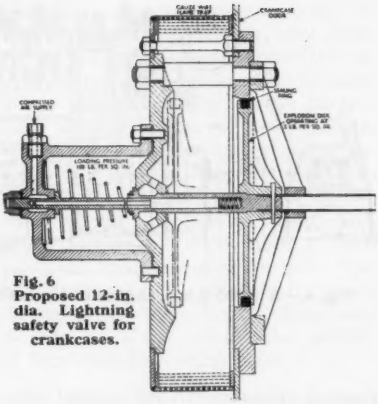

Fig. 6 Proposed 12-in. dia. Lightning safety valve for crankcases.

It would seem that prevention of injury by burning would result only if the released gases could be cooled as they left the crankcase exits. The following experiments were based upon this contention.

The chamber selected for the tests was a disused, but sound, Diesel-engine air-injection bottle having an internal diameter of 18¾ ins. and a length of 12 ft. Air and gas oil were introduced and ignited, the excess pressure produced escaping through a Lightning relief valve of 6 ins. diameter connected to one end of the bottle.

The principal aim was to produce pressure and flame adequately to test the relief valve and flame trap. To simulate more exactly conditions in an engine crankcase, the bottle should have been heated to about 140 degrees F. Heating arrangements were not provided, but it was found that the bottle quickly attained a sufficiently high temperature.

To ensure more positive ignition and to simplify the tests, it was decided to spray paraffin into the bottle in a finely divided state and to ignite the mixture

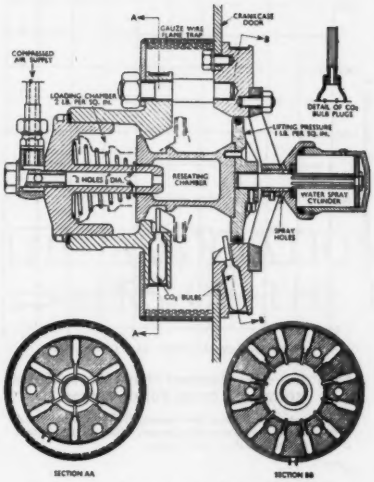

Fig. 7. — Modified Lightning valve.

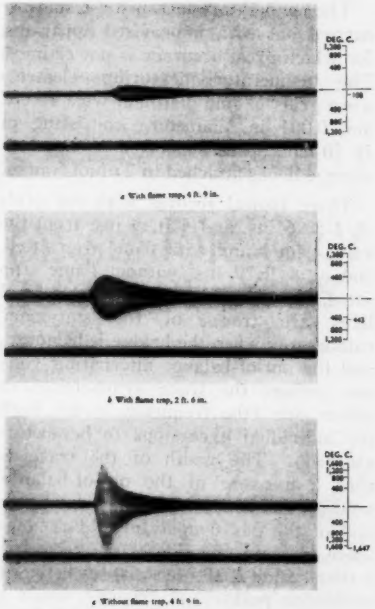

Fig. 8.—Records of gas temperatures.

of air and oil particles by means of an electrically heated wire. The spray forms produced by various types of Diesel-engine injector were examined, but found unsuitable owing to the required small spray angle and excessive penetration in air at atmospheric pressure. Better results were obtained with a continuous-flow swirl type of nozzle, as used in internal-combustion turbines, and a nozzle was made from design data supplied by the Fuel Injection Section of Shell's Thornton Research Centre. This nozzle produced a conical spray with an included angle of about 90 degrees, atomization being obtained with 80 lb. per sq. in. injection pressure.

With paraffin, the flame issuing from the relief valve took the form of irregular tongues up to 18 ins. long. With no air loading on the relief valve, ignition resulted in a series of three or four explosions at intervals of about 1 sec.

As it was known that this particular form of valve was fully capable of preventing a build-up of pressure, efforts were concentrated upon finding means of reducing the temperature of the released gases, and it was decided to test first the effectiveness of the well-known cooling mediums, namely, wire gauze, carbon dioxide and water, and a Lightning valve was made as shown in Fig. 7. The carbon dioxide was contained in a number of small bottle-shaped vessels situated in the path of the escaping gases, while the water sprayer was connected as shown.

The wire gauze was the first to be tried and, in view of the encouraging results obtained during the initial tests, it was decided to pursue this line of investigation before applying either carbon dioxide or water. No. 40 mesh wire gauze was cut and shaped to cover the relief-valve outlet ports, and this alone was sufficient to extinguish a flame 18 ins. long.

The temperature-measuring tests were carried out with improvised apparatus, for which great accuracy is not claimed. The temperature-measuring elements were grids of fine platinum wire (0.002 and 0.004 in. diameter) consisting of 10 50-mm. spans supported on light nichrome hooks attached to Tufnol frames.

Three typical records with the grids at 2 ft. 6 ins. and 4 ft. 9 ins. from the valve center and with flame trap fitted, and at 4 ft. 9 ins. without flame trap fitted, are shown in Fig. 8. The central lines are traces of the stationary cathode-ray when the bridge is balanced, and the out-of-balance alternating voltage swings the trace symmetrical to either side (the frequency is too high for individual excursions to be distinguished). The width of the trace is thus a measure of the out-of-balance voltage, and hence of the grid resistance and of the gas temperature. The sine-wave trace to one side of the record is a time scale; 2/100 sec. elapses between successive peaks.

The results of the test carried out are summarized in Fig. 9. There are some anomalies, but the effect of the flame trap in the tests at 4 ft. 9 ins. from the valve center is beyond question.

The best results were obtained with a flame trap made up of two layers of thick gauze and three layers of thin gauze, the thick layers being on the inside and first to meet the issuing flame. The two inner layers were cut from 20-mesh gauze with wire of 0.02 in. diameter, clear area 36 percent and weight 0.56 lb. per sq. ft. The remaining layers were cut from 40-mesh gauze with wire of 0.01 in. diameter, clear area 36 percent and weight 0.30 lb. per sq ft. The reason for locating innermost the gauze made of the thicker wire is because 0.02 in. diameter wire absorbs about 80 percent as much heat as 0.01 in. diameter wire, and because of its greater weight per unit area the temperature rise will be only about 50 percent of that of the thinner wire.

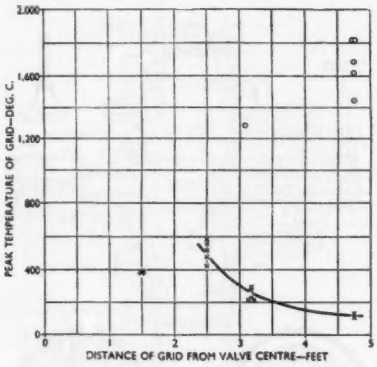

Fig. 9.—Gas temperature at various distances from relief valves.

×=Two thick and one thin gauze, 0.004-in grid wires.
+=Two thick and one thin gauze, 0.002-in. grid wires.
o=No gauze, 0.004-in. grid wires.

The effect of this flame trap was to extinguish completely a flame 15 ft. long and reduce the temperature of the gases issuing from the valve from 1,647 to 108 degrees C. at a distance of 4 ft. 9 ins. from the center.

The relief valve was designed to operate at a pressure of 1 lb. per sq. in. when loaded by air at 2 lb. per sq. in. The reason why such a low loading pressure was used is that it was intended ultimately to fit this valve of an engine where a continuous supply of supercharge air at that pressure was available.

For the next stage it is proposed to erect an eight-cylinder 1,005 b.h.p. trunk-piston engine from the Diesel-electric ship *Auris* at Thornton Research Centre, and after full instrumentation, the engine explosions will be produced in the crankcase whilst operating and at rest. In this way it is hoped to obtain very valuable information regarding pressure waves when oil mist of varying density is ignited at different points.

THE ASSOCIATION OF SENIOR ENGINEERS OF THE BUREAU OF SHIPS

DAVID J. BARRY

THE AUTHOR

Early training consisted of five years shipbuilding apprenticeship in Workman, Clark, and Company, Belfast, combined with the regular Naval Architectural Course in the Municipal College of Technology. From 1924 to 1938, he worked on hull design in Newport News S. B. and D. D. Company and Bethlehem Shipbuilding Corporation, Quincy, Massachusetts. From 1938 to date he has been in Civil Service with the Navy, Principal Naval Architect in charge of Design Arrangements until 1948, and since then Head Civilian in the Conversion Design Branch. He is a Registered Professional Engineer, a member of The Society of Naval Architects and Marine Engineers in addition to holding membership in THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

EDITOR'S NOTE

Because of the many times questions regarding the aims and accomplishments of the Association of Senior Engineers have been raised, Mr. Barry was asked to prepare this article for the JOURNAL.

The Bureau of Ships is a large and complex enterprise having the industrial function of designing, building, and maintaining Naval vessels needed for military support of national policy. Its purposes are "military" but its methods and functions are primarily engineering and scientific. Technological requirements of ships for modern warfare are so diverse and complex that they can be met only through enthusiastic efforts of capable men ambitious for recognition and reward in a professional engineering career system.

Since World War II, civilian engineers in the Bureau have felt that there existed among them a unique community of interest and common body of knowledge which could be shared best through participation in a professional society. Neither the formal organization of the Bureau nor any of the national societies offered satisfactory means for developing within the Bureau an atmosphere which would inspire its engineers to the heights of professional attainment. There developed among engineers a growing concern for the pos-

sibility that the Bureau could neither attract nor hold engineers of the highest ambition unless they were offered every opportunity for professional improvement.

To meet this need there was organized, in 1946, the Association of Senior Engineers of the Bureau of Ships. Its object is to promote the general welfare of all Bureau engineers professionally and socially, to foster a spirit of good fellowship and cooperation, and to maintain high standards of professional ethics and competence. The Association has full approval of the Office of the Secretary of the Navy and the Chief of the Bureau of Ships.

By constitution, policy, and practice, the motives of the Association are characteristic of a professional society. It maintains standards akin to those of national societies and many of its members take an active part in the activities of nationally known engineering societies. Participation in the activities of the Association provides a means of personal contact among engineers for development of professional skill and interchange of professional knowledge. By fostering friendly and informal relations among engineers engaged in the Bureau's work, professional efficiency and working environment is improved for the good of the Naval service.

Meetings of the Association are held locally for reading of technical papers covering the latest development in engineering, electronics, and shipbuilding. Condensed summaries of these papers are submitted for national publication, thus establishing a line of communication between the Bureau and the outside shipbuilding and engineering fraternities.

During the past year the following addresses were given by Association members:

Mr. Robert A. Fyfe, naval architect, *Recent Developments in Plastic Boats.*

Mr. George Sipkin, patent counsel, *Pending Legislation on Patent Rights of Federal Employees.*

Mr. Charles L. Stec, electronic engineer, *Modern Developments in Electronics.*

Since its formation in 1946, the Association has participated in bringing about:

(1) development of an in-service training program for junior engineers,

(2) continuation of advanced study courses for credit at local institutions on both in-service and after hours basis,

(3) establishment of in-service management course for senior engineers,

(4) establishment of civilian technical staff meetings,

(5) organization planning for management of the Bureau,

(6) registration of professional engineers in the District of Columbia,

(7) participation of engineers in career guidance programs of local high schools, and

(8) volunteer inspections of buildings for A-bomb shelters for Office of Civil Defense of the District of Columbia.

The Association participated with management of the Bureau in welcoming newly recruited engineers into the Bureau last Fall. Its professional development committee assisted in forming an internal training program for new engineers recently recruited from a highly competitive market. It sponsored a reception for these young men at the Willard Hotel which was attended by the Chief of the Bureau, Admiral Wallin, and his principal naval and civilian administrators of the Bureau.

For social activities the Association sponsors an annual banquet, a summer picnic, and a stag party. The guests of honor at the banquet are the Chief of the Bureau of Ships and his principal assistants. These social contacts have been extremely valuable to the Bureau in improving morale and communications.

The objectives and progress of the Association have been carefully guided by the earnest work of the following past presidents:

Mr. Albert A. Smith—1946
Mr. John C. Niedermair—1947
Mr. Thomas E. Cassey—1948
Mr. Harold F. Sipe—1949
Mr. Charles G. Emmett—1950
Mr. Samuel E. McCrary—1951
Mr. David J. Barry—1952

The president for 1953 is Mr. John B. Alfers, prominently identified in the plastics industry.

CHANGES IN SHIP CONSTRUCTION METHODS, 1850 TO 1950

ACKNOWLEDGMENT

This is an abridged version of a paper presented at the Spring Meeting of The Institution of Naval Architects, held in London, April 2 to 4, 1952. It appeared in the June 6, 1952 issue of "Engineering." The author is MR. NORMAN M. HUNTER.

Consideration of changes in ship construction methods naturally leads one to think of the distant past when wood was the principal material used for construction. Many methods of the old shipwright craftsman are still in use today. The nature, strength, and means of fastening the joints of the material put a limit to the size of wooden ships. All were small; the famous *Victory*, Nelson's flagship, was only 186 ft. long. Few wood merchant ships exceeded 200 ft. About the beginning of the Nineteenth Century the growth of world trade and the development of steam power pointed to the necessity for larger ships and inspired shipbuilders to introduce iron ties, frames, beams, etc., and, by this composite method, to meet the demand for increased carrying capacity. Although the first iron ship was classed with Lloyd's Register in 1837, the wooden or composite ship retained popularity for many years. Steel was first tried about 1860, but its general use for shipbuilding purposes did not come in for about 35 years afterwards.

For some years, little attention was paid to improving the equipment and layout of shipyards. Good roadways for transporting materials from the machines to the building berths were the exception, and in some yards horses were used to assist in hauling heavy plates to positions alongside the building berths. The lifting appliances at the berths were wooden pole derricks carrying wooden jibs, with rope guys for swinging them by hand labor. Hoisting was by steam winch and lighting was by means of oil lamps.

The piecework method of payment introduced in the 1870's, principally in the iron department, had a great effect in improving not only the quality and speed of carrying out the work, but also the layout of the yard, its machinery and transport arrangements. Under this method of payment, the leader of each large squad of workmen in the plating department accepted the responsibility of a contractor to carry out satisfactorily the preparation and erection of his portion of the work. Payment was made by weekly draws from the contract price, after the inspection and checking of the amount of work done in that period, to the squad leader, who was responsible for the engagement and payment of his assistants and helpers. Small

items of work were done at contract rates by individual platers, or by apprentices. In the case of riveting squads, the senior riveter drew the money and paid all his squad members; but caulkers and drillers usually worked individually.

The desire of both employers and craftsmen to increase output and earnings by reducing the amount of hard manual and unskilled labor brought about a gradual improvement in plant, machinery, hoisting and transporting facilities, and general layout of workshops and yards. The speed of punching machines was raised from about 14 punches per minute to about 30; punching gaps were increased in width to allow wider plates to be worked, and the speed of machines for punching some sections such as frame bars went up to about 40 to 50 per minute. Workshops were rearranged to enable an easier and quicker flow of materials through the machines necessary for their preparation, and in almost all cases machines were brought under cover. Hydraulic power was introduced to drive large bending presses, shearing machines for sections, hoists, and punching machines for shearing out manholes in plates, instead of punching around by small punch and chipping off the burrs by hand hammer and chisel. Portable hydraulic riveting machines, invented in 1871 by R. H. Tweddell, were introduced in place of the fixed machine for riveting frames and floors, and at which these items had to be pulled along for each rivet. These portable machines could put in rivets at speeds of 1500 to 2500 per day, where 300 to 400 per day was a good average by the hand hammer method.

In the early 1900's, electricity for light and power was gradually introduced to displace steam drive and the oil lamp. Some shipyards installed their own generating stations, but in this country the introduction of the supply of electricity in bulk by public companies stimulated the installation of this power to drive the heavy shipyard plant, and also the fitting, plumbing, woodworking, and other departments' machinery by motors on each machine. In the larger yards, at the building berths, the old wooden derrick was replaced by electrically-driven derricks or by traveling or fixed cranes capable of lifting loads of 5 tons or more. In some yards, gantries alongside or over the berths were built, having electric cranes running on top. Palmer's Shipbuilding and Iron Company, at Jarrow, installed large steel cable transporters fore and aft over some of their building berths on which ran electric traveling hoists; and Swan, Hunter, and Wigham Richardson, Limited, completely covered in four of their Wallsend shipyard berths with glass-roofed sheds, served by electric cranes running under the roofs.

Staging round the ships building on the berths came under review, and, though the wooden pole is still much used today, various other methods then came into use. In some cases, the wooden poles were replaced by single steel uprights which could be moved out and in on sliding bases to suit varying widths of ships; in other cases, steel portable trestles were employed, which could be lifted into or out of position by cranes. Some had wood platforms which could be raised and lowered by hand-worked gears. In the building of floating docks, staging was erected on steel brackets, bolted to the vertical side plating. Recently, a very ingenious system of light steel tubing, with specially-designed sockets of various types, by means of which various shapes and types of staging can easily be erected, has gained much favor for staging both outside and inside ships under construction.

Between 1906 and 1910, oxy-acetylene cutting by hand tools came into use for cutting the ends of sections, or awkward curves in plates which previously required to be punched along with small

punch, the burrs being afterwards chipped off by hand chisel; and also for cutting openings in decks, etc., which previously were cut out by hand chisel. Pneumatic power also came into use about this time for working riveting, caulking, and drilling machines, which gradually, over the next few years, almost completely replaced the hand hammer and drilling brace. The painting department also benefited by the introduction of power-driven scaling hammers, steel rotary brushes, sand-blasting and the spraying of paint.

In the shipwright department, a machine combining a hydraulic ram and electric drill came into use for making hatch covers and other similar parts, where two or more thick planks were fastened together by long through irons or bolts; this saved much hand labor. About this time also, pneumatic hand caulking tools came into use for deck-seam caulking, but the greatest improvement of seam caulking was the introduction of the electrically-driven caulking machine, with which the bulk of that work is now done. For planing the surfaces of the wood decks, an electrically-driven machine almost completely eliminated the hand plane; and recently an electric sanding machine has come into use for putting a smooth finish on the surface of the deck.

In the plating department, before 1906, with the exception of changes in methods of handling and transporting materials, no great change had come about in manufacturing methods in shipyards in this country. Up to that time, the drawing office issued to the mold loft particulars from which to draw and fair the ship's lines on the loft floor, and produce a full-size body plan from which the loftsmen made the scrieve boards showing the shape of every frame and floor. For deck beams, a cambered mold was given to the beam squad, showing length of each beam, positions of deck-plate landings, and deck girders, if any, and a mold giving particulars of beam knees. Molds were also provided for marking the intercostals in the double bottom and their connecting angles to double bottom floors. Very little more information was given, except for specially-shaped parts of the ship's structure, and then only by special arrangement made by the foreman of the department concerned with the foreman of the mold loft.

The bars were punched before being heated in the furnace and set. Beams were marked for length and plate landings from the mold; rivet holes, spaced by rule measurement, were punched before cambering. When frames and beams were erected, they were faired into correct positions by shipwrights; and when fairing was completed, the drilling and riveting of frame brackets to tank margins and beam knees to frames was carried out. The shipwrights then lined off the plate landings for tank top, deck, and shell plating after which the platers proceeded to template from the ship the size, shape, and particulars for all rivet connections, plate by plate, putting each plate in position as it was worked.

Gradually these methods were changed; more information and templates were obtained from the mold loft to enable the work to be fabricated ready for its place in the ship's structure, and by 1910 the methods employed in many shipyards for fabricating the work had made much progress. Some yards installed multiple punching machines, which had proved useful for floating-dock construction, and used them very successfully for ship work such as deck plating, bulkheads, casings, and deck houses. One large firm with which the author was connected used this machine for tank top and also side shell planting, for which they fitted an attachment which took account of sheer.

Some Continental shipyards carried this prefabrication to great lengths. In 1911, the author visited a yard in which every part of the ship was prefabricated

before the keel was laid. The work was good and the erection on the berth was quick, but the prefabricating work was slow. The craftsmen were expert and extremely careful; in most cases, they lifted all required measurements themselves from the scrieve boards, and from their working plans. Rivet holes were lined off by a sharp-pointed steel scriber and were center-punched. The punches in the punching machines had a center-finding point turned on them and the plater took care that this point came into the center punch mark in the plate or bar before punching the hole. Such great care was taken when marking the work that, when a chalk line was being struck, a plank was put on its edge close to the chalk line to shield it from any stray breeze which might tend to deflect it. Although none of the British shipyards, so far as the author is aware, at that time carried out prefabrication to so great an extent, yet gradually a closer link-up between mold loft and plating department came about.

About this time, a one-man punching machine came into use, by means of which the plater alone could carry out the work of punching the plate more accurately and quickly than by the old method of employing a number of helpers to assist in moving the plate along as each hole was punched. For shearing the plate, helpers were still required, and, as no satisfactory arrangement for this operation was available, the shipyard with which the author was associated designed, manufactured, and put into operation a one-man machine at the shearing end of the punch which successfully dealt with the operation, and the necessity for employing helpers for both punching and shearing was almost completely overcome. About this time also, high-speed twist drills and radial-arm drilling machines claimed the attention of shipbuilders.

During the last 20 years, a few firms have changed their method from independent squads to specialists in each department, and payment is made for each operation separately, instead of by a contract for the completed job in the ship. For this method, they have rearranged their machines and means of transport through their shops, so that the raw material is placed on marking tables, lined off, and is then transported by overhead crane to the various machines necessary for its preparation. In some cases, caster roller bearings have been installed so that the plates can be easily moved along to or at certain machines, and when fabrication is complete separate erection squads put each part in position in the ship.

An interesting optical method of marking the plate has been put into operation recently in some Continental shipyards. By this method, special drawings for each plate are made by the drawing office to a scale of one-fifth or one-tenth full size. These are then photographed, and the negatives are placed in a projector high above the marking table and a full-sized picture is shown on the material to be marked off. One or two Continental yards and one in this country recently adopted a method of preparing and erecting shell plating first, up to about three strakes above the bilge, and dropping the frames into position afterwards. In these cases, no stage poles are used, the staging being erected on angle-iron brackets which are bolted to the plating, as has been the practice at the building of floating docks. The author fails to see what advantage is gained in this method. He considers more is to be gained in completing the internal structure first.

The latest method of ship construction, which is bringing about a revolution in shipyard layout, machinery, and plant, is by electric arc welding. This method came gradually into use after the development of the covered metal electrode about 1913, which made it possible to deposit weld metal shielded from atmospheric contamination and from being chilled by

too rapid cooling. At first, all arc welding was carried out by hand tools, but now there are various makes of automatic and semi-automatic welding machines of high speed for use either in the shop or aboard ship for work in a more or less horizontal position. The fact that it is easier to weld in a downhand position under cover has led to the provision of large and lofty fabricating sheds, equipped with cranage and handling appliances capable of dealing with large units up to 30 tons or 40 tons weight, and also the provision of storage space close to the building berths to take completed units. This method of fabrication by welding has reduced the number and type of sections required for construction. The author regrets to see that a tendency still persists to fit a riveted gunwale bar to attach the top deck stringer plate to the shell sheer strake in the otherwise all-welded ship.

A mixture of welding and riveting requires careful consideration if strength is to be maintained. From the practical point of view, the punching of rivet holes near the edge of each plate is a source of weakness, and both the punching and riveting, particularly hydraulic riveting, stretches both the bar and the plating edges. It is easily seen that no strain can be taken up by this connection till the adjoining parts of the structure have stretched, and this is a source of weakness. Welding has also greatly altered the shipyard steel-working machinery. The ordinary punching and shearing machine and the planing machine are no longer necessary. Some shipbuilders have replaced these by high-speed oxy-acetylene flame planing machines, which cut the plates to exact size and bevel the edges to the required angle for welding in one operation. Other shipbuilders still prefer to shear and plane by high-speed machines. Machinery for rolling, straightening, flanging, and joggling is still necessary, but air-compressing plant can be reduced as pneumatic riveting is no longer required, and the amount of both caulking and drilling is greatly reduced.

Against this reduction of steel-working machinery is the installation of welding plant, and as electrical consultants differed in their views as to whether alternating or direct current was the better and more economical to install, we find some shipyards equipped with alternating and others with direct. Equally good welding can be done with either type, but with alternating current on board ship, either on the building berth or when fitting out afloat, there is more danger to the operator of shock, and the lengths of the leads are more restricted than with direct current.

The author's opinion is that in the workshop, where most of the welding is done in the down-hand position and the leads to the operating tool can be kept short, alternating current for welding is satisfactory; but aboard the large ships, either on the building berth or fitting out afloat, direct current is safer, quite as economical, and a better, more universal and satisfactory servant than alternating current. The shipyard with which the author is connected is fully equipped for completely welding large ships on all berths, bus-bars being run along each side of each berth, supplied with direct current at from 70 to 80 volts from large rotary generators which take their driving power direct from the 6,000-volt alternating current supply to the works.

Angle-iron smithwork in the welded ship has almost completely disappeared, and blacksmith work has been greatly reduced, so far as forging and hand welding are concerned, by the introduction of the band saw, oxy-acetylene cutting and electric welding. In the early days of iron and steel ships, stern frames were forged; this method gave place to steel casting and the latter is now in the process of being replaced by fabrication by electric welding. Changes in shipwright work methods are principally concerned with the laying of

wood decks and launching arrangements.

Changes in launching are concerned principally with the means of releasing the ship on the ways. The old method of preventing the ship moving was by having a wood trigger or balk of timber between projections bolted on the outer sides of forward lengths of fixed and sliding ways. These were released either by dropping weights, which were fitted in vertical slides above their upper ends, or by a shipwright at each one releasing it by a blow of his maul. When ships increased in size and launching weight, this arrangement was replaced in most shipyards by one or more hydraulic cylinders, bolted to the standing launchway near the midship length at either side. When the cylinder was pumped up, the end of the ram pressed against the end of a steel lever. The other end of this lever engaged with the sliding way by projecting into a steel-lined opening and prevented its movement till the water in the cylinder was released. This hydraulic launching gear is still in use, but has largely been superseded by a mechanical gear, worked by a system of levers, the controlling lever having a weight on the end which causes it to drop when a wire-rope attachment by which it is held is cut.

Aluminum alloy is at present claiming attention, principally on account of its lighter weight compared with steel for superstructures, lifeboats, and in some cases, masts. So changes of materials, dimensions, and methods go steadily on. In the earlier days, many details and fittings were left to the experienced judgment of the craftsmen and foremen directly at the ship, with only general instructions from the drawing office. Nowadays, with greater elaboration of organization, but not necessarily greater efficiency, innumerable plans and instructions are issued from the drawing office for every conceivable detail.

In the old days, there were some examples of remarkable speed of construction. In 1856, the *Terror,* a floating battery of 2000 tons displacement, built for the bombardment of Kronstadt, was built by Palmer's in the remarkable short time of three months. In 1890, the *Tosari,* a 300-ft. three-deck ship, was built at Wallsend in seven months; in 1907, the *Arawa,* a 460-ft. three-deck ship, was built in 8½ months; and the *Salvador,* a 220-ft. ship with two decks, was built in 1909 by Swan, Hunter, and Wigham Richardson, Limited, in two months. Some quick speeds were also accomplished in shipping machinery and equipment, an instance being the TSS *Matatua,* a 448-ft. ship with five boilers, built by Workman, Clark and Company in 1907. The two sets of engines, the boilers, uptakes, funnel, two masts, all deck winches, and engine room and stokehold ventilators, were placed on board in less than 48 hours, the insulation and all fittings being complete on boilers before shipping.

DISCUSSIONS

of the article "Wartime Logistics Aboard Ship" by Captain Carl J. Lamb, USNR, appearing in the May 1952 issue of THE JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, INC.

BY COMMANDER WALTER J. BUCKLEY, USN

The article "Wartime Logistics Aboard Ship" was read with great interest and amazement. Captain Lamb states that the main intent was to provoke discussion, to cause thought with the hope that it would be useful to reserve officers ordered to engineering duty afloat. The article has considerable merit for discussion purposes, but I cannot help but pity the poor reserve officer who attempts to follow the captain's observations and put them into practice.

We, who have been operating engineers for any length of time, know that there are many "tricks of the trade." To set forth any of these tricks as standard operating procedures, is to tread on very dangerous ground. These "tricks" can only be applied after thorough familiarization with any one ship and its power plant, coupled with enough engineering know-how to realize the hazards involved in departing from the principles laid down in the BuShips Manual and the manufacturers' instruction books.

The BuShips Manual has always been the engineers "bible" and a strong persuader to convince the "Old Man" that some of his pet ideas are not authorized, or perhaps even downright dangerous. Captain Lamb apparently dropped the Manual over the side and went merrily, and, no doubt effectively on his way, operating on the assumption that the end justifies the means.

Having served as Engineer Officer of a BB, CA, and CVB, since 1942 I am a little aghast at several of the Captain's recommendations to the reserve officer. I know several carrier skippers who would be very happy to have a "chief" who was not continually making dire predictions as to what would and could happen if the requirements of Chapter 51, regarding tube blowing, were not religiously complied with. The boiler record sheets of the ships mentioned in the Captain's article must have evinced great interest in the Bureau.

I agree wholeheartedly with the Captain that waste aboard ship is our greatest enemy, both from an economical as well as an efficiency standpoint. Training and education is the crying need to correct this prevalent condition. There is an attitude existing among too many of the officer and enlisted per-

sonnel in the fleet today that there is always "more" in GSK, so why take care of what we have? These same people fail to realize that the tools and equipment are paid for by the same taxes that cause much comment and concern when March 15 rolls around, but is then forgotten until the next year.

Captain Lamb's article has provoked discussion and now causes the following thoughts:

1. How was trim and draft constantly adjusted when all tanks were at all times 100% full? This is no mean trick for the oil king even when differences of specific gravities are considered.

2. How was the excessive amount of waste oil accounted for? The figure of 100,000 gallons of waste per year seems out of all proportion to that required to change lube oil, and trying to pour even half that amount through the crankcase of an OS2U would leave little time left for flying. I will let the matter of rancid vegetable oils stand with the hope that some supply officer will take up that subject.

3. Was the hazard of berrylium poisoning, due to shock-broken lamps considered, or was "cutting down the load" the prime consideration for the fluorescent lamp installation?

4. Was the introduction of auxiliary exhaust into the fuel oil heaters accompanied by an "unauthorized" change to piping? What was the guarantee that the auxiliary exhaust line would not become flooded with fuel oil in case of a heater leak? Not having the "bible" at hand memory tells me that the pressure differential on heat exchanger equipment will favor leakage to the side that will result in the minimum of damage.

5. Not being familiar with the laundry installation on the ships under discussion, it is with hesitation that I ask. how did the make up feed get mixed up in the laundry operation in the first place?

6. What method or instruments were used to determine that the boilers were operating on 25% excess air? As this eliminated slag and soot on the fire sides it appears that this should be disseminated to all ships without delay.

To the young reserve officer about to undertake engineering duty I would offer this word of advice: Stick to prescribed operating procedures until you are sure of a better way, and then submit your recommendations to your type commander. Beware of the unauthorized alteration as you would a plague.

BY LIEUTENANT DANIEL MAHONEY, USNR

Editor's Note: The following letter to Captain Lamb is reproduced in its entirety.

1 July 1952

Dear Captain Lamb,

I have just read your article "Logistics aboard Ship" in the May Journal of the ASNE. I have served as Engineer Officer of a Westinghouse Geared Turbine Destroyer Escort of 12,000 SHP and as Engineer Officer of a 1630 ton Benson Class Destroyer of 50,000 SHP.

I have always felt that the Navy has not put the proper emphasis on fuel economy down through fleet, force and type commanders, but has relied too much on the BuShips Manual and BuShips letters, etc.

The result of this has been, I feel, that the commanding officers, who can do the most good in requiring fuel economy, are left out of the picture. If the commanding officers were critically judged by their superiors for the fuel performance of their ships it would

cause them (1) to require the best standards of engineering practice from their engineers and (2) to eliminate full bells and other excessive oil-wasting bells and shipboard practices. I believe that the present system whereby the Quarterly Summary fuel performance reports and fuel performance in general is not emphasized by the chain of command is causing commanding officers to worry very little about performance.

The engineer cannot by himself steam the ship at 100% but he can do much good and should be encouraged to use your methods. Of the methods you describe, I have used and been very pleased with (1) Sea Water Laundry rinses, (2) burning old lube oil, (3) keeping unnecessary lights turned off, (4) adjusting trim, (5) "Boosting" steam on standby boilers (6) watching closely for water waste in laundry and scullery (I believe sculleries cause 75% of destroyer types water troubles), (7) keeping wing tanks full, (8) burning 25% excess air for "clear stack" and (9) I am a very great believer in the boiler compound and cornstarch treatment for evaporators, especially when coupled with "chill shocking."

Your watering the LSTs reminds me of last year's "LantFlex" operation when a DMS ran out of water. They asked the Task Group Commander for water and all he could muster from 8 fleet tankers, 16 destroyers and four other destroyer escorts was 1,000 gallons each from three tankers. We (a DE) gave the DMS 8,500 gallons of feed water, the total feed and fresh capacity of our ship being 16,000 gallons.

Economy in the Navy is very sadly neglected, I am afraid, and anyone who tries to foster it should be congratulated. You have written a very much needed article.

Very truly yours

Daniel Mahoney

BOOK REVIEWS

MODERN MARINE ENGINEERING

By D. W. Rudorff, Dipl. Ing., M. Inst. F., F.R.S.A.

Published by Temple Press Limited, Bowling Green Lane, London, E. C. 1, 1952. 154 pages; 9s 6d net.

Reviewed by Commander James E. Halligan, USN

A volume of the Technical Trends Series, this book is of special interest to marine engineers and students. It provides easy reading of a technical subject consisting of a brief history of marine engineering with particular regard to design trends and the reasons for these trends. Emphasis is placed on trends that have developed in the last decade in the design of machinery for merchant and naval vessels. The subject is discussed under the headings of General Aspects of Propulsion Plant, Steam Boilers, Geared Steam Turbine Drive, Turbo-Electric Propulsion, Diesel Engines, Diesel-Electric Propulsion, Gas Turbines, Ships' Steering Gear and Auxiliary Machinery. A bibliography is included to assist those who desire more detailed information. Photographs and sketches are used to illustrate the text.

HANDBOOK OF ENGINEERING FUNDAMENTALS

Second Edition

By Ovid W. Eshbach

× + 1322 pp., 1952, John Wiley & Sons, Inc., New York, Chapman and Hall, Ltd., London; $10.00.

This revised edition of Eshbach incorporates a complete review and revision of the first edition, published in 1936. The important changes are:

The engineering tables have been enlarged to include standard structural sizes for aluminum. The table on standards and symbols has been brought up to date.

The treatment of mathematics has been completely revised, with greater stress being placed on statistics, determinants and vector analysis.

The section on fluid mechanics has been divided into two parts (viz., mechanics of incompressible fluids and aerodynamics.)

The section on electricity and magnetism has been completely revised, as have been the sections on metallic and non-metallic engineering materials.

The Society has learned with sincere regret since the publication of the August, 1952, Journal of the following deaths among its members:

METZEL, JEFFREY C. Naval Member

SCHULTZE, WILLIAM H., JR., Associate Member

CHANGES IN MEMBERSHIP

The Society takes a great deal of pleasure in announcing that the following have become members since the publication of the August, 1952, JOURNAL:

NAVAL

Belanger, Edward Eugene, Lieutenant, USNR,
Power Shift Supt., Goodyear Tire and Rubber Co.,
Mail: 511 South West Ave., Jackson, Mich.

Brooks, David Mooreman, Lieutenant, USN,
Route 3, Box 2432, Bremerton, Wash.

Durfee, Elbert Foster, Commander, USN,
5907 Wyngate Drive, Bethesda, Md.

Gibson, Muscoe Minor, Lieutenant, USNR,
USS *Tabberer* (DE 418),
Mail: 114 Shawomet Ave., Somerset, Mass.

Holleman, James Henry, Lieut. Commander, USNR,
Central Office Foreman, Toll Plant Dept.,
C & P Telephone Company of Virginia,
Mail: 190 First Parish Road, Scituate, Mass.

Hudgins, William Davis, Commander, USN,
931 Pleasant St. (Ravinia Station), Highland Park, Ill.

Langen, William A., Jr., Lieutenant, USNR,
Aeronautical Engineer, Goodyear Aircraft,
Mail: P. O. Box 2161, Uniontown, Ohio

Lord, Robert N., Lieutenant, USN,
USS *Salem* (CA 139),
Mail: 859 Lawrence St., Lowell, Mass.

Lucy, Philip P., Commander, USNR,
2892 Kimball Terrace, Norfolk 12, Va.

Pignomi, Anthony Richard, Ensign, USN,
83 Aberdeen Road, New Hyde Park, N. Y.

Shores, Robert Merritt, Jr., Ensign, USN,
USS LST 840, % Fleet P. O., San Francisco, Calif.

Smith, Frank Walter, Jr., Lieutenant, USN,
USS *Deal* (AKL 2), % Fleet P. O., San Francisco, Calif.

Stromberg, Herman Arthur, Lieutenant (j.g.), USN,
53 Dorothea Road, Arlington, Mass.

Tate, Robert L., Lieutenant, USNR,
President, Tate Engineering & Supply Co., Baltimore, Md.,
Mail: % Kerby Cottage, Aquidneck Ave.,
Prospect Road, Middleton, R. I.

Thiele, Otto W., Lieutenant, USNR,
USS *Widbey* (AG 141), % Fleet P. O., San Francisco, Calif.

Thomas William Kenneth, Lieutenant, USN,
USS *Heerman* (DD 532), % Fleet P. O., New York, N. Y.

Wakefield, Charles William, Lieutenant, USNR,
Engineer, General Electric Co.,
Mail: 48 Pine St., Scotia 2, N. Y.

Watson, Walter James, Commander, USNR,
Assistant to Executive Vice-President, Control Instrument Co., Inc.
67 35th St., Brooklyn 32, N. Y.

Wilson, Robert Murray, Lieutenant, USNR,
Contract Administrator, Control Instrument Co., Inc.
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Geyer, George Eugene, Assistant to Executive Vice-President,
Control Instrument Co., Inc., 67 35th St., Brooklyn 32, N. Y.

Gordon, Charles F., Executive Secretary, Machines, Inc.,
2707 Federal St., Philadelphia 46, Pa.

Hyland, John Joseph, President, Control Instrument Co., Inc.,
67 35th St., Brooklyn 32, N. Y.

Carliss, Oswald Sheldon, Director of Engineering,
Yale and Towne Manufacturing Co., Philadelphia, Penna.

Smedley, Walter, Sales Engineer, Dravo Corp.,
Mail: 1483 Broad Street Station Bldg., Philadelphia 3, Penna.

Wilton, Bartel,
Director, Wilton Fijenoord, Box 22, Schiedam, Holland

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Henschel Corporation, Amesbury, Mass.

Gray, Douglas H.,
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Commander in Chief, Royal Thailand Navy,
Dehonbars, Thailand

RESIGNED

CIVIL
Moreland, H. D.

REINSTATED

NAVAL
Goldstein, Marton L.

ASSOCIATION NOTES

ORIGINAL ARTICLES

The editor of the JOURNAL is most anxious to obtain manuscripts of original articles on subjects of interest to naval engineers. Any manuscript accepted for publication becomes the property of the Society which copyrights it upon publication. Authors are paid from $40.00 to $150.00 depending upon length, interest and professional value.

The rules for manuscripts are as simple as we can make them.

1. They must be legible (typewritten, double-spaced preferred) since no proof is submitted to authors for correction prior to printing.

2. Single copy only is required.

3. Mathematical formulae used must be set up, preferably by hand printing, so that there can be no question as to symbols, subscripts and exponents.

4. Any drawing submitted must be black on white. A cloth or paper tracing is acceptable but not required.

5. Photographs may be negatives, but glossy prints are acceptable.

6. Include on a separate page a short biographical sketch(es) of the author(s). 50 to 100 words for each author is desired.

Manuscripts should be mailed addressed to:

Secretary-Treasurer
American Society of Naval Engineers
605 F St., N. W.
Washington 4, D. C.

Manuscripts accepted will not be returned unless specifically requested by the author. If returned, they will be in the condition which has resulted from the work of the printer and the engraver. Immediately following publication, the author is furnished 10 reprint copies of his article free of charge. Additional copies may be purchased from the Society if the request is received 30 days prior to the publication date which is the 25th of the issue month. Estimate of cost of additional reprints, which will vary with the nature of the article and the number of copies ordered, will be furnished on request as soon as possible after the article is set up.

Manuscripts not accepted will be returned, postpaid, by the Society.

Manuscripts which are accepted will be published in the earliest JOURNAL which has not yet been closed (60 days before publication) and for which insufficient material is already on hand.

SUBJECT MATTER AND AUTHORS

To assist the editor in programming future issues, the help of all members is solicited. To make it easy, the last page in this issue is readily detachable as you will find. This page has blanks for two entries.

(a) What subject would you, as a member, like to see covered by an article in the JOURNAL.

and

(b) Who do you consider best qualified to prepare such an article authoritatively, and what is his address (if you know).

Any of these forms which are filled in and mailed to the Society will be received with thanks and the editor will follow up to get the suggested articles prepared.

PHOTOGRAPHS

Photographs of current or historical interest to readers of the JOURNAL are desired. Any which are accepted by the Society will be purchased by the Society at a standard price of $5.00 each. Such purchase *will not* include any copyright by the Society, but the contributor must hold the Society free from any charge of violation of any previous copyright.

NOTICE OF DEATHS

The Society has no satisfactory machinery for obtaining notice of deaths of members. It is particularly desired that we receive such notice upon the death of any past officer, past member of the Council or member of more than twenty years' standing with photographs and short obituaries. It will be appreciated greatly if any member who learns of the death of a member will advise the Secretary-Treasurer.

SOCIETY LAPEL BUTTONS

Shown below is an illustration of the lapel button of the Society. It is believed that it will be conceded that this is a very fine dignified insignia. It is one-half inch in diameter.

The oak leaves and lettering are red on a gold background.

It is available to all members at fifty cents (50c) each.

LIFE MEMBERSHIPS

Any member may now purchase a life membership under the following rules:

(a) Any dues paid for the year in which life membership is purchased will be credited to the cost of the life membership.

(b) Life memberships are non-transferable and terminate with the death of the member.

(c) No refund will be made on account of death or resignation of a life member.

(d) Life membership will vary in cost with the age of the member at his next birthday following application, as follows:

Over 55 years	$125.00
40 to 55 years	175.00
25 to 39 years	225.00
Under 25 years	250.00

(e) All life memberships paid in shall be protected by a transfer on the books of the Society of Series G, U. S. Government 2½ per cent bonds. Thus a life membership will be established. It will be credited with moneys paid in for life memberships and debited with the regular amount of annual dues for each life member each year.

LOCAL CHAPTERS

Local Chapters of the American Society of Naval Engineers may now be authorized by the Council. The following rules for recognition of Local Chapters have been adopted by the Council:

(a) Twenty or more regular members, Naval or Civilian, may apply for a Charter as a Local Chapter.

(b) Each application must be accompanied by a list of members and a copy of local By-laws. The latter must meet the following minimum requirements.

1. All financial dealings of the local Chapter must be independent of the Society and can in no way obligate the Society as a whole. The local chapter shall set up on a non-profit basis. All accounting shall be local.

2. Each active local Chapter shall receive from the Society a grant of $0.50 per year for each naval member, civil member or associate who resides in the local area and who associates himself with the local Chapter. This grant may be used by the local Chapter to defray any necessary expenses, including (a) Letterheads, (b) Notice cards, (c) Postage, (d) Minimum rental allowance, (e) Secretarial service (part time).

3. Any technical papers presented at local chapter meetings, shall be submitted to the Secretary-Treasurer of the Society for consideration for publication in the JOURNAL. Any paper accepted will be paid for at regular rates.

4. Each local chapter shall submit a quarterly report of its activities to the Secretary-Treasurer. These reports must reach Washington, D. C. prior to 15 January, 15 April, 15 July and 15 October. This report shall contain a list of active local members as of the first day of the quarter for the purpose of computing the amount of grant.

5. Associate members of the Society shall be eligible for membership in a Local Chapter, entitled to all the privileges of other members except voting and holding office.

Permission is granted to reprint any original article contained herein if the following conditions are met:

a) Credit is given to the JOURNAL with reference to the issue.

b) Credit is given to the author.

c) If the author is a military officer or a civilian employe of the Department of Defense, the following note shall be carried:

"The views expressed herein are the personal ones of the author and are not necessarily the official views of the Department of Defense or of a Military Department."

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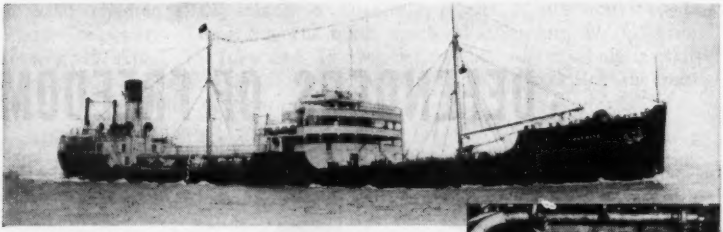

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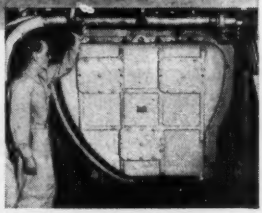

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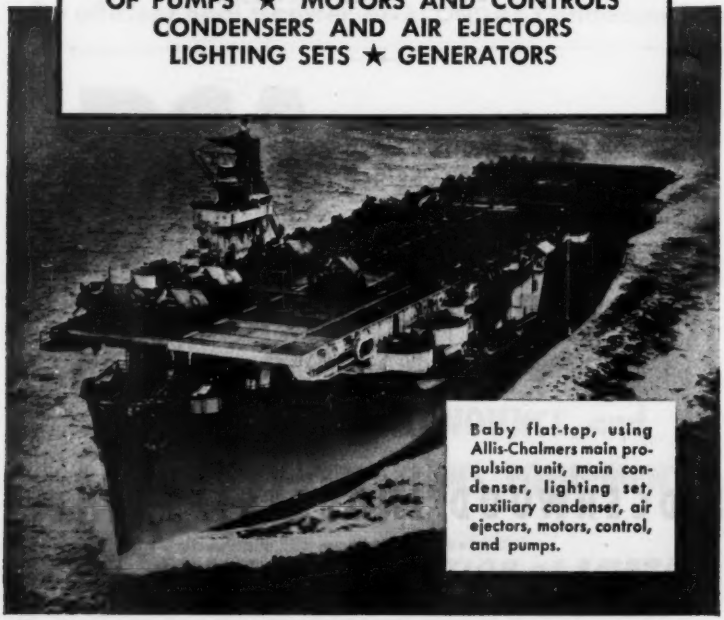

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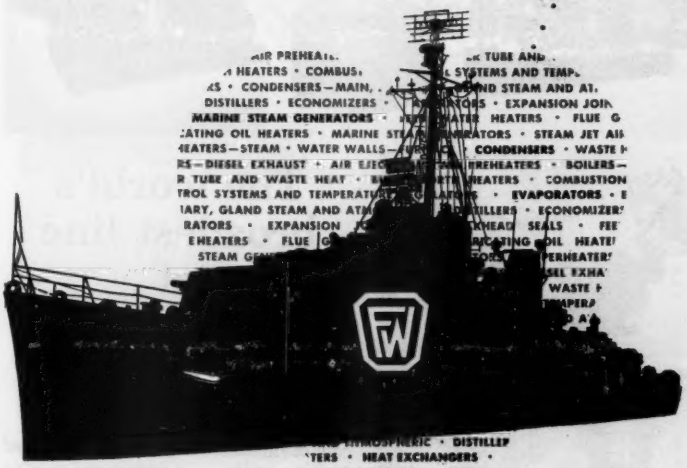

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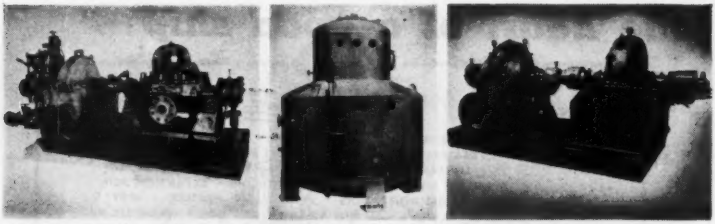

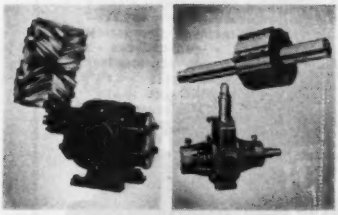

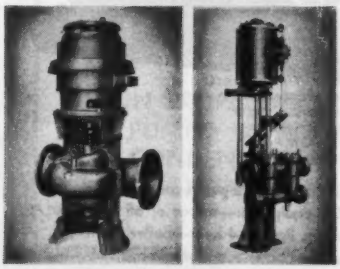

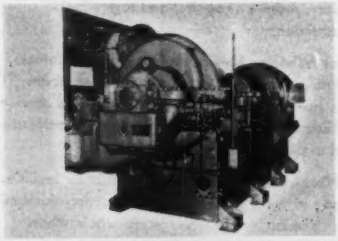

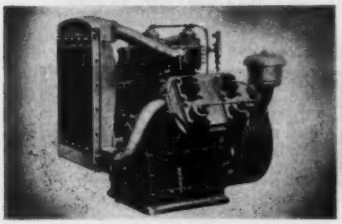

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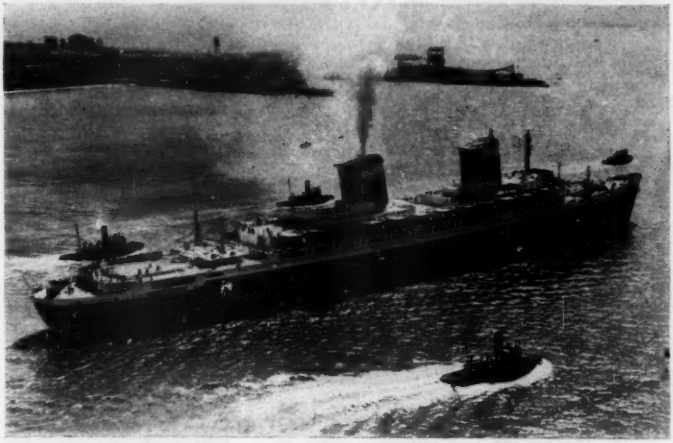

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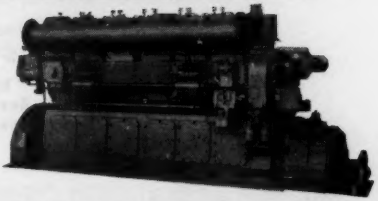

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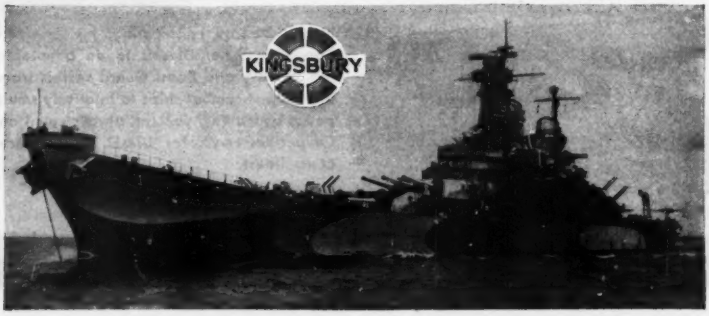

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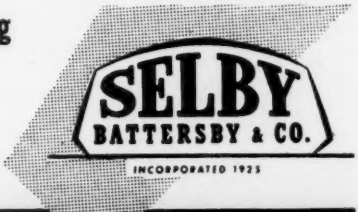

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